Environmental Indicators

For National State of the Environment Reporting

biodiversity

Australia: State of the Environment
Environmental Indicator Report

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Preface

The Commonwealth State of the Environment Reporting system supports the *National Strategy for Ecologically Sustainable Development* and helps Australia meet its international obligations, such as those under *Agenda 21* and the OECD environmental performance reviews. The first independent and comprehensive assessment of Australia's environment, *Australia: State of the Environment 1996* was released by the Commonwealth Environment Minister in September of that year.

The next step in the evolution of the reporting system is to develop a set of environmental indicators that, properly monitored, will help us track the condition of Australia's environment and the human activities that affect it. To help develop these indicators, Environment Australia has commissioned reports recommending indicators for each of the seven major themes around which Commonwealth state of the environment reporting is based. The themes are:

- human settlements
- biodiversity
- the atmosphere
- the land
- inland waters
- estuaries and the sea
- natural and cultural heritage.

Clearly, none of these themes is independent of the others. The consultants worked together to promote consistent treatment of common issues. In many places issues relevant to more than one theme receive detailed treatment in one report, with cross-referencing to other reports.

Report authors were asked to recommend a comprehensive set of indicators, and were not to be constrained by current environmental monitoring. One consequence of this approach is that many recommendations will not be practical to implement in the short term. They are, however, a scientific basis for longer term planning of environmental monitoring and related activities.

These reports are advice to Environment Australia and have been peer reviewed to ensure scientific and technical credibility. They are not necessarily the views of the Commonwealth of Australia.

The advice embodied in these reports is being used to advance state of the environment reporting in Australia, and as an input to other initiatives, such as the National Land and Water Resources Audit and the Australian Local Government Assocation's Regional Environmental Strategies.

SUMMARY

A key set of 53 environmental indicators for biodiversity is recommended for Australian state of the environment reporting at the national scale. Of these, 12 relate to pressures on biodiversity, 17 to the condition of biodiversity, and 34 to responses to loss of, or perceived threats to, biodiverstiy. Monitoring strategies and approaches to interpreting and analysing each of the indicators are discussed, and possible sources of data are noted. Recommendations are also made for further development of environmental indicators for biodiversity.

Aims of the study

- present a key set of indicators for biodiversity for national state of the environment reporting;
- ensure that the list of indicators adequately covers all major environmental themes and issues;
- examine each indicator in detail to ensure that it is rigorously defined and measurable and in an interpretive framework;
- identify suitable monitoring strategies for each indicator – including measurement techniques, appropriate temporal and spatial scales for measurement and reporting, data storage and presentation techniques, and appropriate geographical extent of monitoring;
- identify relevant data sources for each indicator, if these are available;
- define the baseline information that is needed to properly interpret the behaviour of the indicators.

Table of Contents

BACKGROUND

Commonwealth State of the Environment Reporting

In 1992 Australia's *National Strategy for Ecologically Sustainable Development* (Council of Australian Governments 1992) was endorsed by the Commonwealth, all State and Territory Governments and Local Government. The objectives of this strategy are:

- to enhance individual and community well-being and welfare by following a path of economic development that safeguards the welfare of future generations;

- to provide for equity within and between generations; and

- to protect biological diversity and maintain essential ecological processes and life-support systems.

The strategy called for the introduction of regular state of the environment (SoE) reporting at the national level to enhance the quality, accessibility and relevance of data relating to ecologically sustainable development.

The broad objectives of state of the environment reporting for Australia are:

- to regularly provide the Australian public, managers and policy makers with accurate, timely and accessible information about the condition of and prospects for the Australian environment;

- to increase public understanding of the Australian environment, its conditions and prospects;

- to facilitate the development of, and review and report on, an agreed set of national environmental indicators;

- to provide an early warning of potential problems;

- to report on the effectiveness of policies and programs designed to respond to environmental change, including progress towards achieving environmental standards and targets;

- to contribute to the assessment of Australia's progress towards achieving ecological sustainability;

- to contribute to the assessment of Australia's progress in protecting biological diversity and maintaining ecological processes and systems;

- to create a mechanism for integrating environmental information with social and economic information, thus providing a basis for incorporating environmental considerations in the development of long-term, ecologically sustainable economic and social policies;

- to identify gaps in Australia's knowledge of environmental conditions and trends and recommend strategies for research and monitoring to fill these gaps;

- to help fulfil Australia's international environmental reporting obligations; and

- to help decision makers to make informed judgements about the broad environmental consequences of social, economic and environmental policies and plans.

The first major product of this process was *Australia: State of the Environment 1996* (State of the Environment Advisory Council 1996) — an independent, nation-wide assessment of the status of Australia's environment presented in seven major themes: human settlements; biodiversity; the atmosphere; the land; inland waters; estuaries and the sea; and natural and cultural heritage.

In Australia: *State of the Environment 1996,* each of these themes is presented in a chapter that follows the Organisation for Economic Co-operation and Development's (OECD) (1993) Pressure–State–Response model (see also DEST 1994). In the interpretation of this model applied in the 1996 State of the Environment Report, pressures are defined as human activities that affect the environment. Natural events such as floods, storms and non-anthropogenic fires are considered to be aspects of the state or condition of the environment. Responses are defined as actions taken by people in response to perceived environmental problems or potential problems. The pressures on biological diversity are set out in the report's chapter on biodiversity (Chapter 4), together with an account of the current condition or state of biological diversity, and of the responses (political, social etc.) to those pressures.

Australia: State of the Environment 1996 is the first stage of an ongoing evaluation of how Australia is managing its environment and meeting its international commitments in relation to the environment. Subsequent state of the environment reports will assess how the environment, or elements of it, have changed over time, and the efficacy of the responses to the pressures on the environment. The next national SoE report is due in 2001, consistent with the regular reporting cycle of four to five years. In order to assess changes in the environment over time it is necessary to have indicators against which environmental performance may be reviewed. As pointed out in Australia: State of the Environment 1996:

> *"In many important areas, Australia does not have the data, the analytical tools or the scientific understanding that would allow us to say whether current patterns of change to the natural environment are sustainable. We are effectively driving a car without an up-to-date map, so we cannot be sure where we are. Improving our view of the road ahead by enhancing the environmental data base is a very high priority. Our intended destination is a sustainable pattern of development, but it is not always clear which direction we need to take to get there".*

The development of a nationally agreed set of indicators is the next stage of the state of the environment reporting system. This report recommends environmental indicators for biodiversity. Indicators for the land (Hamblin 1998), inland waters (Fairweather and Napier 1998) and estuaries and the sea (Ward *et al.* 1998) have been developed in consultancies run in parallel with the development of indicators for biodiversity. Indicators for the atmosphere, natural and cultural heritage and human settlements have been developed about six months behind the first four themes.

Environmental indicators

Environmental indicators are physical, chemical, biological or socio-economic measures that best represent the key elements of a complex ecosystem or environmental issue. An indicator is embedded in a well-developed interpretive framework and have meaning beyond the measure that it represents.

Repeated measurements of the variables that make up the indicator in various places and times, and in a defined way, comprise the monitoring program for that indicator. Comparison of this repeated set of measurements with a benchmark set or condition provides the basis for detecting change. Over time, in the case of a state or condition indicator, this change can be matched to particular pressure indicators and response indicators to assess both the nature of effects of particular pressures and the efficacy of our management responses. The scale at which the information is needed for management purposes dictates the scales (spatial and temporal) at which the monitoring program must resolve changes in each indicator.

The key set of indicators is defined as the minimum set which, if properly monitored, provides rigorous data describing the major trends in, and impacts on, Australian biological diversity. This key set should include: indicators that describe pressures exerted on biological diversity; indicators of its condition or state; and indicators of responses to the pressures, or to changes in the condition or state. The set of indicators should be considered at three levels of biological organisation — ecosystems, species and genes — and should be as comprehensive as possible without being unwieldy.

The selection criteria for national environmental indicators are listed below (from DEST 1994); the set of key indicators should meet as many of these as possible.

Each indicator should:

1 serve as a robust indicator of environmental change;

2 reflect a fundamental or highly valued aspect of the environment;

3 be either national in scope or applicable to regional environmental issues of national significance;

4 provide an early warning of potential problems;

5 be capable of being monitored to provide statistically verifiable and reproducible data that show trends over time and, preferably, apply to a broad range of environmental regions;

6 be scientifically credible;

7 be easy to understand;

8 be monitored regularly with relative ease;

9 be cost-effective;

10 have relevance to policy and management needs;

11 contribute to monitoring of progress towards implementing commitments in nationally significant environmental policies;

12 where possible and appropriate, facilitate community involvement;

13 contribute to the fulfilment of reporting obligations under international agreements;

14 where possible and appropriate, use existing commercial and managerial indicators; and

15 where possible and appropriate, be consistent and comparable with other countries' and State and Territory indicators.

Scope of biological diversity

The accepted definition of biological diversity (sometimes shortened to biodiversity) is: the variety of all life forms — the different plants, animals and microorganisms, the genes they contain and the ecosystems of which they form part.

Australia: State of the Environment 1996 points out that conservation and maintenance of biodiversity are important for four reasons:

- Biodiversity provides the critical ecosystem processes that make life possible and are often taken for granted. Healthy, functioning ecosystems are necessary to maintain the quality of the atmosphere, including the air we breathe, and to maintain and regulate the climate, fresh water, soil formation, cycling of nutrients and disposal of wastes.

- Preserving biological diversity is important for ethical reasons; no species or generation has the right to sequester Earth's resources solely for their own benefit.

- There are aesthetic and cultural reasons for the maintenance of biological diversity. Many Australians place a high value on native plants, animals and ecosystems, which are essential to a sense of cultural identity, spiritual enrichment and recreation.

- Elements of biological diversity are important for economic reasons: controlling pest plants, animals and diseases; pollinating crops; providing food, clothing, building materials, medicines and many kinds of raw materials; and as the basis for much tourism (Beattie 1995; State of the Environment Advisory Council 1996).

Biological systems are organised hierarchically from the molecular through the ecosystem to the landscape level. Logical classes such as genotypes, populations, species, communities and ecosystems are heterogeneous; all members of each class can be distinguished from one another. The variety of biological configurations at all levels is extremely large, currently unknown and probably unmeasurable. Yet for monitoring and reporting on the condition of biological diversity there has to be some acceptable baseline against which change can be measured.

Figure 1, adapted from Williams (1996), shows a biological hierarchy with precision of measurement increasing from the higher more heterogeneous levels down to the molecular level, and practicality (including effort and cost) increasing in the opposite direction. A decision on which level of surrogacy to use depends on the scale of measurement and reporting and the resources available. The greater the level of precision, the more useful the result. For national state of the environment reporting it will be possible, in some cases, to use sub-sets of taxa as surrogates for biological diversity, although vegetation classes and environmental domains are commonly adopted at the national scale because they are available at a consistent level of detail. In addition, higher levels of organisation integrate ecological processes and functions such as

Biodiversity surrogates

Advantage: precision as a measure of biological diversity.		Advantage: cost, efficiency and more inclusive of ecosystem processes.
low		high
↓	LANDSCAPES	↑
↓	ECOSYSTEMS	↑
↓	ASSEMBLAGES	↑
↓	SPECIES	↑
↓	POPULATIONS	↑
↓	INDIVIDUALS	↑
high	CHARACTERS	low

Figure 1. Levels of biological diversity surrogacy. Precision increases from the landscape to the character level, but cost decreases and ease of measurement increases in the opposite direction. Adapted from Williams 1996.

nutrient and energy cycling, which result partly from components of biological diversity.

The term biological diversity is a relatively recent one and, given the broad definition of it, there is considerable scientific debate on what it is, and how it is distributed. As pointed out by Angermeier and Karr (1994), it is common to see biological diversity used synonymously with species diversity; many people interpret the term more narrowly, equating conservation of biological diversity with nature conservation. This erroneous view leads to biological diversity being seen in a very restricted way. For example, in rural landscapes biological diversity is assumed to exist only in patches of remnant vegetation scattered over agricultural land. This misunderstanding has led to great uncertainty about what it is that should be measured, managed and monitored. A focus on the species level ignores most biological diversity (Angermeier and Karr 1994). To continue with the example of rural lands, this assumption results in management of remnant vegetation being seen as the action to conserve biological diversity. It ignores the fact that ecosystem function (soil formation, nutrient cycling etc.) is a result of interactions of other elements of biological diversity — as well as those in remnant vegetation patches — which also must be identified, measured, managed and monitored.

Indicators for biological diversity

The concept of indicators of biological diversity is even more recent. Indicators are poorly developed (Bakkes *et al*. 1994), and information is limited compared with the easily measured indicators of air or water quality, which provide reliable descriptions. Bakkes *et al*. (1994) point out that the term biological diversity is an abstract and "eco-centric" concept that attracted little policy attention until recently when it was identified as a resource. They also point out that indicators of biological diversity are biased strongly towards species and away from the ecosystem as a whole, and that further progress towards generalised indicators of biological diversity poses substantial difficulties. This is borne out by an examination of 20 state of the environment reports or environmental reports from ten countries and several papers on suggested environmental indicators. This found that only four indicators of pressure on biological diversity out of 68 used in the various studies were common to five or more of these (Table 1). Similarly, only seven out of 41 indicators of the condition or state of biological diversity were used in five or more studies, and none of the 36 indicators for responses was used in five or more studies. The most commonly used indicators were: the extent of vegetation clearance or conversion (an indicator of pressure); and the conservation status of species and the extent of protected areas (two indicators of condition or state).

Table 1

Indicators of biological diversity taken from 20 state of the environment reports

Indicators of biological diversity taken from 20 state of the environment reports from Australia (1996 Commonwealth, ACT, NSW, SA and WA), environmental reports from Canada, Denmark, Finland, Hong Kong, Italy, Japan, the Netherlands, Norway and the United Kingdom, and reports on environmental indicators from OECD, United Nations Environment Programme (UNEP), World Bank and World Resources Institute (WRI)/ World Conservation Union (IUCN)/ UNEP (extracted by the State of the Environment Reporting Unit, Environment Australia). Only indicators used in 5 or more of the sources are listed.

INDICATOR OF	NO. REPORTS USED
pressure	
Vegetation clearance, fragmentation, conversion	10
Threatening processes (other than clearance)	8
Introduced species or genes	6
Grazing	5
state	
Conservation status of species	16
Extent of protected areas	12
Distribution and abundance of species	9
Extent of intact or unmodified plant/animal communities	6
Changes in distribution and abundance	6
Distribution and abundance of introduced species	5
Size and shape of protected areas	5

The OECD's (1993) core set of indicators for biodiversity and landscape was:

Indicators of pressure

- habitat alteration and land conversion from its natural state,
- land use changes,
- introduction of new genetic material and species;

Indicator of condition or state

- threatened or extinct species as a share of total species known;

Indicators of response

- protected area as a percentage of total area by ecosystem type,
- protected species as a percentage of threatened species.

At present, the OECD is drafting a new set of indicators of biological diversity and landscape.

It should also be noted that the cause and effect relationships between pressure, state and response indicators implied by the Pressure–State–Response model are "soft". Sorting the indicators into categories of pressure, state (or condition) and response gives groupings which are indicative of relationships between human activities and the condition of the environment. Response indicators measure some of the efforts made by humans to address perceived environmental problems or potential problems. Changes in the state (or condition) and pressure indicators may give some indication of whether these responses have been effective; but there may not necessarily be a causal relationship between the two, so a cautious approach to interpretation is essential.

Harding and Eckstein (1996) point out that the theme area of biological diversity will be the most difficult of all the environmental media/systems for which we might wish to develop a concise set of indicators.

Conceptual and policy approaches to biological diversity

At present there is no broad Commonwealth, State or Territory legislation covering the conservation of biological diversity, although there are a number of laws covering the management and conservation of the environment and natural resources, including flora and fauna (SoE Advisory Council 1996). In June 1993, Australia ratified the International *Convention on Biological Diversity* which was one of the outcomes of the Earth Summit held in Rio de Janeiro in June 1992. The key aims of this convention are:

> *The conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding.*

The aims of this convention have been incorporated in the *National Strategy for the Conservation of Australia's Biological Diversity* (Commonwealth of Australia 1996), which has been endorsed by the Commonwealth, State and Territory governments. The goal of this strategy is to protect biological diversity and maintain ecological processes and systems. The strategy aims to provide the link between current activities and the effective identification, conservation and management of Australia's biological diversity. The *National Strategy for the Convention of Australia's Biological Diversity* is closely linked to the *National Strategy for Ecologically Sustainable Development* (Council of Australian Governments 1992). Implementation of the *National Strategy for the Conservation of Australia's Biological Diversity* will require actions that affect virtually all of Australia's terrestrial, aquatic and marine ecosystems. Most ecosystems will continue to be subject to a multiplicity of uses, many of which depend on the maintenance of, or are impacting on, biological diversity.

Because the *National Strategy for the Conservation of Australia's Biological Diversity* provides a framework within which to conserve biological diversity and has been agreed to by the Commonwealth and all State and Territory governments, it is also the ideal context within which to assess performance towards these conservation goals. The National Strategy calls for identification of the condition or state of biological diversity, and of the pressures on it (called threatening processes in the National Strategy). It lists a number of objectives and actions (responses) designed to help achieve these goals.

The third Conference of the Parties to the *Convention on Biological Diversity* (which Australia ratified in June 1993) was held in Buenos Aires in November 1996. At that meeting the Parties adopted two formal decisions which reinforce Australia's need to develop a mechanism to monitor biological diversity and to develop indicators to assess progress. Those decisions are:

> Paragraph 5 of Decision III/9 which encourages all *Convention on Biological Diversity* Parties to set measurable targets in order to achieve biodiversity conservation and sustainable use objectives; and
>
> Paragraph 2 of Decision III/10 which formally "endorses" work under the *Convention on Biological Diversity* to establish a "core set" of biodiversity indicators to be included by governments in their national implementation reports.

Approach to selecting indicators

The first step in this consultancy was to assemble a comprehensive list of potential indicators and evaluate them against the objectives and actions of the *National Strategy for the Conservation of Australia's Biological Diversity*. The list was extracted from the literature, from consultations with scientists, managers and policy makers, and from the workshop on Key Environmental Indicators of Biodiversity in State of the Environment Reporting organised by the State of the Environment Reporting Unit of the Commonwealth Department of the Environment, Sport and Territories and held in Sydney on 4–6 June 1996. This process was undertaken to determine whether or not all of the issues relating to pressures on, and condition or state of, biological diversity and the responses to those pressures and changes in condition were taken into account in the list of potential indicators to be considered. It satisfies the second aim of the consultancy: to ensure that the list of indicators adequately covers all major environmental themes and issues.

The list of potential indicators was then examined in consultation with the coordinators developing indicators for state of the environment reporting for inland waters (Peter Fairweather), the land (Ann Hamblin), estuaries and the sea (Trevor Ward), and the atmosphere (Mike Manton), and Allan Haines and John Higgins of the State of the Environment Reporting Unit. Those indicators of biological diversity which were deemed to be more appropriate to inland waters, the land, estuaries and the sea, and the atmosphere were incorporated within those themes. For example, some indicators of forest biological diversity more appropriate to the forestry sector have been developed in the land theme, and indicators being developed under the Montreal Process (Montreal Process Implementation Group 1997) are discussed in Hamblin (1998).

The remaining indicators were then rearranged within the Pressure–Condition–Response model used for national state of the environment reporting and assessed in relation to reporting priorities. Those deemed to be key indicators — because they report on issues of high priority, comprise the minimum set necessary to track changes in biological diversity and are capable of being implemented now or in the near future — are presented below. In Table 2, these indicators have been scored against the selection criteria proposed by DEST (1994) for their suitability as key indicators. A summary of the proposed key indicators is provided in Table 3.

This consultancy reports on all these steps. Those indicators which formed part of the initial comprehensive set, but which were not regarded as part of the key set because they report on lower priority issues, are poorly developed, or have some other major drawback, have been incorporated in Appendix 1. Those indicators that relate to biological diversity but which are dealt with by indicators for land, inland waters, estuaries and the sea, and atmosphere are also included in Appendix 1.

No attempts have been made in this report to provide any costings of any of the indicators proposed. This was not part of the brief for the consultancy, and given the fact that many of the indicators will require considerable research and development details such as cost are not available.

A composite indicator consists of two or more indicators aggregated into a single function, with the aim of presenting information on a particular subject in a more useable way (Harding and Eckstein 1996). The final phase of indicator development should be to establish if some indicators can be aggregated into composite indicators which will reduce the number of indicators without losing any of the interpretive ability provided by the disaggregated set. This is a research phase beyond the scope of this consultancy.

Regionalisations and scales for reporting on national environmental indicators

Choosing the appropriate spatial and temporal scales for expressing indicators of biological diversity is critical. If an inappropriate scale is chosen, data from monitoring programs will fail to reflect adequately ecosystem changes at scales that are meaningful for management agencies. Scales in space and time for national state of the environment reporting should be closely linked with the scales at which management takes place, and spatial scales, where possible, should be congruent with natural ecosystem boundaries.

Temporal scales will vary depending on the indicator, and should be established separately for each monitoring program. Various issues and elements being reported on via indicators will have different natural dynamics, and monitoring programs to detect change will need to employ temporal scales appropriate to the natural scales of change, but modified according to the management needs for information on rates of change. For example, elements that change only slowly may need to be measured infrequently in order to detect change, but if a small change is of great importance then measurement needs to be frequent to detect whether or not small changes are occurring.

Since detection of important change is the key rationale for state of the environment reporting, it is essential that any reporting is accompanied by estimates of uncertainty and risk for the data, as well as the information reported (interpretation of the data). Estimating the risk of indicating no change when change has occurred — and the converse, indicating change when no substantial change has occurred — will be critical in the establishment and maintenance of the credibility and broad acceptance of the state of the environment reporting process. Managers of all resources operate on a risk-acceptance basis, and they need to know (or estimate) how risky a decision or process is in terms of established objectives.

Regionalisations provide an essential framework for focusing attention, summarising patterns, aggregating information and developing indicators, as well as allocating priorities and resources (Thackway and Cresswell 1995). Indicators of biological diversity at the national level need to be expressed at a scale of regions which have been constructed to represent ecological realities. Most regionalisations in common use are constructs drawn up for social or political reasons; State, Territory and local government boundaries are good examples of these types of regionalisations, as are Statistical Local Areas. While regions of this kind are needed for cataloguing and reporting on social, political and demographic statistics, plants, animals and microorganisms do not recognise them. Biological diversity patterns are constrained by evolution, climate, substrate, landform and a number of other ecological conditions.

The Interim Biogeographic Regionalisation for Australia (IBRA) (Thackway and Cresswell 1995) has been developed as a framework for setting priorities in the National Reserves System Program, which has as its primary aim the conservation of biological diversity. The IBRA is intended to define, map and describe the major ecosystems of Australia and is an integrated classification of biotic and abiotic variation. IBRA regions represent a landscape-based approach to classifying the land surface, including attributes of climate, geomorphology, landform, lithology, and characteristic flora and fauna. This approach has meaning to ecologists and land managers (Thackway and Cresswell 1995) and, subject to verification for particular indicators, should prove useful for state of the environment reporting (SoE Advisory Council 1996).

An Interim Marine and Coastal Regionalisation for Australia (IMCRA) (IMCRA Technical Group 1997) has been developed through the collaborative efforts of State, Northern Territory and Commonwealth marine management and research agencies. IMCRA is a regional planning framework that encompasses data and information on ecological patterns and processes. This is seen as an essential step for conservation and ecosystem management. IMCRA was developed using the best available biological and physical data. Biological data included distribution of sponges, fishes, corals and seagrasses while physical data sets included bathymetry, coastal geomorphology sediments, currents, water chemistry and water temperature. These data were verified and then classified into ecologically meaningful regions comprising similar combinations of environmental attributes. The regionalisation has two main layers, firstly ten broadscale marine provinces and secondly 60 meso-scale regions. As is the case for IBRA, this bioregionalisation will provide a sound basis for environmental reporting at State and Commonwealth levels.

IMCRA has been developed to provide a regional planning framework for Australia's Exclusive Economic Zone (EEZ) to assist in planning for biodiversity conservation and sustainable resource management. One of its main applications will be to identify deficiencies in the existing systems of marine protected areas and to assist decision makers in setting priorities to fill these gaps. IMCRA forms a crucial part of the knowledge base for planning a national representative system of marine protected areas to ensure that the full range of Australia's marine habitats and species is managed adequately.

Several IMCRA map products have been developed. These include:

- demersal meso-scale (i.e., 100s to 1000s km in length and width) regionalisation extending out to the 200 m depth contour;
- pelagic provincial scale (i.e., 1000s to 10 000s km in length and width) regionalisation extending out to the edge of the boundary of the EEZ; and
- demersal provincial scale (i.e., 1000s to 10 000s km in length and width) regionalisation extending out to the edge of the boundary of the EEZ.

State, Northern Territory and Commonwealth agencies are now drawing on the meso-scale regionalisation as a regional-level planning framework within which to carry out more detailed surveys to map and describe the major ecosystems within each meso-scale bioregion. It is agreed by these agencies that the meso-scale level will be used to identify priority areas for establishing a national representative system of marine protected areas.

The IMCRA meso-scale regions provide an appropriate set of ecologically based spatial units for use in state of the environment reporting for many of the draft indicators proposed in this report for marine regions. Accordingly, references to IMCRA in this report refer only to the meso-scale IMCRA regionalisation. It should be noted that the meso-scale regionalisation extends only to the 200 m depth contour. Where state of the environment reporting is required beyond the 200 m contour and out to the limit of the EEZ, the demersal province regions may be used to provide a representation of ecosystem distribution.

Some pressures and responses are more appropriately considered at a finer scale of expression. This is usually the local scale, which for national state of the environment reporting is the Statistical Local Area or, in some cases, catchment areas.

Vegetation types

A number of indicators of pressures on, or condition of, biological diversity utilise vegetation types or their marine equivalents — e.g. 2.1 Extent and rate of clearing, or major modification, of natural vegetation or marine habitat; 2.2 Location and configuration of remnant vegetation; 11.1 Ecosystem diversity; 11.2 Number and extent of ecological communities of high conservation value; and 13.1 Extent of each vegetation or marine habitat type incorporated within protected areas.

At present, the only map and description of native terrestrial vegetation types which is consistent across the continent is the one compiled at a scale of 1:5 million by J.A. Carnahan for Volume 6 of the Atlas of Australian Resources (Commonwealth of Australia 1990). This map provides a broad overview of the distribution of major vegetation types. However, the classification is insensitive to many of the changes that state of the environment reporting will be concerned with. More detailed maps of forests produced by the National Forest Inventory are now available (Sun *et al.* 1996). They include the best current digital map data on forest distribution across the continent, but are only available for forests.

In coastal and marine environments there are no equivalents, even at the most generalised level. In the case of the 200 mile Exclusive Economic Zone, the information is generally limited. More detailed information is available for the continental shelf. The entire EEZ will take many years to map and describe. There is no single source of information on the distribution of major marine vegetation types. Mapping of mangroves, seagrasses and macroalgae in the southern half of the continent is being undertaken by CSIRO in collaboration with the States, but to date there are no distribution maps available for most of the northern half (northern Western Australia, Northern Territory and, except for seagrasses, the Gulf of Carpentaria coast of Queensland). CSIRO has mapped seagrasses in the Gulf and Torres Strait. Information on mangrove and seagrass distributions on the east coast of Queensland is held by Queensland Department of Primary Industries and Australian Institute of Marine Sciences. These data are being compiled and assessed in the development of the IMCRA regionalisation (see "Regionalisations and scales for reporting on national environmental indicators", above).

Indicators of diversity, representation, extent of clearing etc. require a measure of the variation within vegetation types. Such a measure is not available from the existing continental-scale vegetation maps (Commonwealth of Australia 1990), which were not compiled for such a purpose. This is acknowledged in the accompanying text (p. 10): "It is important to recognise that the formal code for any mapping unit represents only a spatial generalisation as no stand of vegetation is ever entirely uniform".

There are several widely used systems for classifying vegetation, which produce different vegetation types and different descriptions of the internal variation within types. Similarly, vegetation types recognised at local scales (which may be at the scale of 1:25 000 as in the ACT or north-eastern NSW) may be different from those recognised at IBRA-region scales (1:500 000). It is important to note that the scale of vegetation mapping must be appropriate for regional management decisions. Currently, it is difficult to reconcile most locally based classifications with broader classifications such as the one in Volume 6 of the Atlas of Australian Resources (Commonwealth of Australia 1990).

A priority for state of the environment reporting should be the production of a consistent vegetation classification system throughout Australia, which should include marine vegetation; mangroves, seagrasses and macroalgae. The classification should be hierarchical, with lower-level classes (local and sub-regional) nested within higher-level classes (regional and continental). As an example, CSIRO Wildlife and Ecology recently produced maps of modelled pre-1750 vegetation types for part of the south-eastern forests (Austin and Cawsey 1996; CSIRO 1996*a*, b, c). These vegetation types were mapped at a scale of 1:100 000, and then aggregated into vegetation classes mapped at a regional scale of 1:500 000. In this way, the variation within classes at the regional scale is expressed quantitatively. If local-scale classifications, capable of being agglomerated hierarchically, existed across the continent, national reporting and monitoring could be made wholly compatible and consistent with reporting and monitoring at the local government scale. A national classification should incorporate both structure and floristics, with floristics as attributes at lower levels. Higher-level classes based on structural attributes could be mapped at the IBRA or IMCRA region, or even national, scale and lower level classes could be mapped at more local scales.

Many existing local and sub-regional scale classifications are likely to be amenable to agglomeration into higher-level classes such as structural types. The first step in producing a consistent national-level classification is a study to assess the feasibility of such a classification, including the compatibility of existing classifications and their suitability for higher-level agglomeration (see "Research and development needs", below).

The term "community" is used hereafter to refer to local-level classes, and vegetation types or marine habitat types refer to regional or continental level classes.

Target taxa

With many of the proposed indicators, it will be impossible to measure all species or populations of all taxa. Accordingly, a small suite of taxa will need to be chosen for analysis. Such taxa should be representative of both taxonomic and biological or ecological species diversity at the bioregional level.

It is desirable that a description of the state of the environment is not restricted to species listed as rare or threatened. Although changes in the distribution and abundance of these taxa are of concern, it is also important to detect changes in common or widespread taxa. Some taxa common now may not necessarily be so in the future. Monitoring changes in widespread taxa will also provide a wider national perspective on the effects of broadly threatening processes such as climatic change.

Taxa chosen for use as indicators should be selected using the following criteria:

Biological/ecological representativeness

1 Habitat specificity — the degree to which a species occurs in a variety of habitats or is restricted to one or two specialist sites within a region.

2 Geographic range — whether a species occurs over a wide area within a bioregion or is endemic to a particular small area within the region.

3 Local population size — whether the taxon is found in large populations somewhere within a region or is present only in small populations within the region. Clearly the size of populations is a measure with different scales for different species.

4 Life span — whether the species is long- or short-lived. Ideally, this should account for both the time to first reproduction and the average length of time over which the taxon remains reproductively active. Such detailed information is available for a limited range of taxa.

5 Reproductive strategy — whether the species reproduces sexually or asexually.

Each of these parameters has a continuous distribution, and taxa should be selected along this continuum.

Taxonomic representativeness
Although the above groupings will go some way to ensuring taxonomic representativeness — in that only some taxa will be applicable to a given group — in cases where a choice is available for any of these groups taxa should be chosen to maximise representativeness of the full range of taxonomic species diversity. It is important to sample and cover the taxonomic spectrum.

Sensitivity to particular pressures
When particular pressures on biological diversity can be identified as being significant within a region, it is useful to choose at least some target taxa that are likely to be sensitive to these pressures. For example, while widespread species that occur naturally in large populations are likely to be affected by habitat fragmentation, species with small disjunct populations may be less affected.

Practicality of sampling and analysis
Taxa which are relatively inexpensive to collect (preferably non-destructively) should be chosen. As far as possible, taxa for which as many indicators as possible are measurable, interpretable and informative should be chosen.

Existing knowledge
Wherever possible, preference should be given to taxa for which there is a stable taxonomy and existing biological knowledge.

Amenability to laboratory rearing and captive breeding
In some instances it may be desirable to undertake laboratory-based analyses of large numbers of specimens. Choosing taxa that are amenable to captive breeding is therefore desirable.

Cross-regional comparability
In order to enable cross-regional comparisons, it is desirable that a deliberate decision be made to include in the analyses some species that occur in a number of regions. This is one reason why rare and threatened taxa should not be chosen to the exclusion of all others.

Table 2

Number of selection criteria for indicators that each proposed indicator meets

Number of selection criteria for indicators that each proposed indicator meets, to be monitored over all jurisdictions. Those indicators being developed as part of other theme reports: estuaries and the sea (Ward *et al*. 1998) and inland waters (Fairweather of Napier 1998) have not been scored (i.e., 3.1, 3.2, 5, 7)

	INDICATOR	CRITERIA FOR INDICATOR SELECTION															TOTAL
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
	INDICATORS OF PRESSURES																
1.1	Human population distribution and density	+	+	+	-	+	+	+	+	+	+	+	-	-	-	?	10
1.2	Change in human population density	+	+	+	+	+	+	+	+	+	+	+	-	-	-	?	11
2.1	Extent and rate of clearing or major modification of natural vegetation or marine habitat	+	+	+	+	+	+	+	+	+	+	+	+	+	+	?	14
2.2	Location and configuration or fragmentation of remnant vegetation or marine habitat	+	+	+	+	+	+	+	+	+	+	+	+	+	+	?	14
3.1	Rate of extension and abundance of exotic species into each IBRA																
3.2	Pest numbers																
4.1	Distribution and abundance of genetically modified organisms	-	+	+	?	?	?	?	-	-	?	+	+	-	?	?	4
5	Pollution																
6	Areal extent of altered fire regimes	-	+	+	-	+	+	+	-	?	+	+	+	+	-	?	9
7	Human induced climate change																
8.1	Lists and numbers of organisms being trafficked and legally exported	+	+	+	-	+	+	+	+	+	?	+	+	+	+	?	12
8.2	Number of permits requested and issued for legal collecting or harvesting by venture	+	+	+	-	+	+	+	+	+	?	+	+	+	+	?	12
8.3	Proportion of numbers collected over size of reproducing population	+	+	+	+	+	+	+	-	-	?	+	+	+	?	?	10
8.4	Ratio of bycatch to target species	+	+	+	-	+	?	+	?	-	?	+	+	-	+	?	8
	INDICATORS OF CONDITION																
9.1	Number of subspecific taxa	+	+	+	-	+	+	+	+	-	+	+	+	+	?	?	11
9.2	Population size, numbers and physical isolation	+	+	+	+	+	+	+	+	+	-	+	+	+	?	?	12
9.3	Environment amplitude of populations	+	+	?	+	+	+	-	-	+	-	+	+	-	?	?	8
9.4	Genetic diversity at marker loci	+	+	+	-	+	+	-	-	?	+	+	?	-	?	?	7
10.1	Number of species	+	+	+	-	+	+	+	+	+	+	-	-	-	+	?	10
10.2	Estimated number of species	-	+	+	-	+	-	+	-	-	+	-	-	-	-	?	5
10.3	Number of species formally described	+	+	+	-	+	+	+	+	+	+	+	+	-	-	?	11
10.4	Percentage of number of species described	-	-	+	-	+	-	+	-	-	+	-	-	-	-	?	4
10.5	Number of subspecies as a percentage of species	+	+	+	-	+	+	+	+	-	+	+	+	+	?	?	11
10.6	Number of endemic species	+	+	+	-	+	+	+	-	-	+	+	-	-	+	?	9
10.7	Conservation status of species	+	+	+	-	+	-	+	+	+	+	+	+	-	+	?	11
10.8	Economic importance of species	-	-	+	-	+	-	+	-	?	-	-	-	-	-	?	3
10.9	Percentage of species changing in distribution	-	+	+	+	+	+	+	-	-	-	+	+	-	-	?	8
10.10	Number, distribution and abundance of migratory species	+	+	+	+	+	+	+	-	?	-	+	+	+	+	?	11
10.11	Demographic characteristics of target taxa	+	+	-	+	+	+	+	-	-	-	+	+	+	+	?	10
11.1	Ecosystem diversity	-	+	+	+	+	+	-	-	+	+	+	+	+	+	?	11
11.2	Number and extent of ecological communities of high conservation potential	-	+	+	+	+	+	?	-	?	+	+	+	+	+	?	10

Table 2 (cont.) Number of selection criteria for indicators that each proposed indicator meets

	INDICATOR OF RESPONSE	CRITERIA FOR INDICATOR SELECTION															TOTAL
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
12	Integrated bioregional planning	+	+	+	-	+	+	+	+	+	-	+	+	+	-	?	11
13.1	Extent of vegetation type, marine habitat type in protected areas	+	+	+	-	+	+	+	?	+	?	+	+	-	+	?	10
13.2	Number of protected areas with management plans	+	+	+	-	+	+	+	+	+	-	+	+	-	+	?	11
13.3	Number of interest groups involved in protected area planning	-	-	+	-	+	-	+	-	-	-	+	+	-	-	?	5
13.4	Resources committed to protected areas	-	-	+	-	+	-	+	-	-	-	-	-	-	-	?	3
14	Proportion of bioregions covered by biological surveys	+	+	+	-	+	+	+	?	+	-	+	+	+	+	?	11
15.1	The number of recovery plans	+	+	+	-	+	+	+	+	+	-	+	+	-	+	?	11
15.2	The amount of funding for recovery plans	-	+	+	-	+	?	+	?	+	-	+	+	-	+	?	8
16.1	Number of ex-situ research programs	+	+	+	-	+	+	+	+	+	-	+	+	-	+	?	11
16.2	Number of releases to the wild from ex-situ breeding	+	+	+	-	+	+	+	+	+	-	+	+	-	+	?	11
17.1	Number of management plans for ecologically sustainable harvesting	+	+	+	-	+	+	+	+	+	-	+	+	-	+	?	11
17.2	Effectiveness of bycatch controls	-	+	+	-	+	+	-	-	?	-	+	+	-	+	+	8
18.1	Area of clearing officially permitted	+	+	+	-	+	+	+	+	+	-	+	+	-	+	?	11
18.2	Area cleared to area revegetated	-	+	+	-	+	?	+	-	?	-	+	+	-	+	?	7
18.3	Number of lending institutions considering biological diversity	+	+	+	-	+	?	+	+	+	-	+	+	-	+	?	10
19.1	Number of management plans for exotic/alien/genetically modified organisms	+	+	+	-	+	+	+	+	+	-	+	+	-	-	?	10
19.2	Number of research programs for exotic/alien/genetically modified organisms	+	+	+	-	+	+	+	+	+	-	+	+	-	-	?	10
19.3	Funding for research and control of exotic/alien/genetically modified organisms	-	+	+	-	?	?	+	-	-	-	+	+	-	-	?	5
20	Control over impacts of pollution	-	+	+	-	+	+	+	-	-	-	+	+	-	+	?	8
21	Reducing the impacts of altered fire regimes	?	+	+	-	+	?	+	-	-	-	+	+	-	-	?	6
22	Minimising the potential impacts of human -induced climate change on biological diversity	-	+	+	-	+	+	+	-	-	-	+	+	-	+	?	8
23.1	Number of local governments with management plans for biological diversity	+	+	+	-	+	+	+	-	-	-	+	+	-	-	?	8
23.2	Number of companies with management plans for biological diversity	+	+	+	-	+	?	+	-	-	-	+	+	-	-	?	7
24.1	Number of species described per reporting cycle	+	+	+	-	+	+	+	+	+	-	+	+	-	+	?	11
24.2	Number of taxonomists involved per reporting cycle	+	+	+	-	+	+	+	?	?	-	+	+	-	-	?	8
24.3	Amount of funding for taxonomy	-	+	+	-	+	?	+	-	-	-	+	+	-	-	?	6
24.4	Number of research programs into surrogates	?	+	+	-	+	+	-	-	-	-	+	+	-	-	?	6
24.5	Number of research programs into role of biological diversity in ecological processes	?	+	+	-	+	+	?	-	-	-	+	+	-	-	?	6
24.6	Number of long-term ecological sites	?	+	+	?	+	+	+	?	-	-	?	-	+	-	?	6
24.7	Percentage of budgets spent on conservation	+	+	+	-	+	?	+	+	+	-	+	+	-	-	?	9
24.8	Amount of indigenous ethnobiological knowledge	-	+	+	-	+	+	+	-	?	-	+	+	+	-	?	8
25.1	Local government management of biological diversity	+	+	+	-	+	?	+	-	-	-	+	+	-	-	?	7
25.2	Involvement of community groups in conservation	+	+	+	-	+	?	+	-	-	-	+	+	-	-	?	7
26	Australia's international role in conservation	-	+	+	-	+	?	+	-	-	-	+	+	-	+	?	7

Table 3

Summary of indicators proposed for development as indicators of biological diversity for national state of the environment reporting.

ISSUE	PRESSURE	CONDITION	RESPONSE
Human population growth, density and demand on natural resources	1.1 Human population distribution and density 1.2 Change in human population density		12 Integrated bio-regional planning 23.1 The number of local governments with management plans for biological diversity 23.2 The number of companies with management plans for biological diversity
Clearing, fragmentation, degradation of native vegetation or marine habitat	2.1 Extent and rate of clearing, or major modification of natural vegetation or marine habitat 2.2 Location and configuration or fragmentation of remnant vegetation or marine habitat		13.1 Extent of vegetation type or marine habitat type in protected areas 13.2 Number of protected areas with management plans 13.3 Number of interest groups involved in protected-area planning 13.4 Resources committed to protected areas 18.1 Area of clearing officially permitted 18.2 Area cleared to area revegetated 18.3 Number of lending institutions considering biological diversity
Alien or exotic species	3.1 Rate of extension and abundance of exotic species into each IBRA 3.2 Pest numbers		19.1 The number of management plans for exotic (or alien) and genetically modified organisms 19.2 The number of research programs into impact on, and control of, exotic (or alien) and genetically modified organisms 19.3 The amount of funding spent on research into and control of exotic (or alien) and genetically modified organisms compared with the amount estimated to be required.
Genetically modified organisms	4.1 Distribution and abundance of genetically modified organisms		See Indicators 19.1–19.3

Table 3 (cont) Summary of indicators proposed for development as indicators of biological diversity for national state of the environment reporting.

ISSUE	PRESSURE	CONDITION	RESPONSE
Pollution	See other reports on Environmental Indicators for National State of the Environment Reporting		20 Control over the impact of pollution on biological diversity
Altered fire regimes	6 Areal extent of altered fire regimes		21 Reducing the impacts of altered fire regimes
Human-induced climate change	See report on Environmental Indicators for National State of the Environment Reporting on the Atmosphere		22 Minimising the potential impacts of human-induced climate change on biological diversity
Harvesting	8.1 List of numbers of organisms being trafficked or legally exported 8.2 Number of permits requested and issued for legal collecting or harvesting 8.3 Number collected over size of reproducing population by species 8.4 Bycatch to target species in trawl fisheries		17.1 The number of management plans for ecologically sustainable harvesting 17.2 Effectiveness of bycatch controls
Genetic diversity		9.1 Number of sub-specific taxa 9.2 Population size, numbers and physical isolation 9.3 Environment amplitude of populations 9.4 Genetic diversity at marker loci	
Species diversity		10.1 Number of species 10.2 Estimated number of species 10.3 Number of species formally described 10.4 Percentage of number of species described 10.5 Number of sub-species as a percentage of species 10.6 Number of endemic species 10.7 Conservation status of species 10.8 Percentage of species of economic importance 10.9 Percentage of species changing in distribution 10.10 Number , distribution and abundance of migratory species 10.11 Demographic characteristics of target taxa	15.1 The number of recovery plans 15.2 The amount of funding for recovery plans 16.1 Number of *ex-situ* research programs 16.2 Number of releases to the wild from *ex-situ* breeding

Table 3 (cont) Summary of indicators proposed for development as indicators of biological diversity for national state of the environment reporting.

ISSUE	PRESSURE	CONDITION	RESPONSE
Ecosystem diversity		11.1 Ecosystem diversity 11.2 Number and extent of ecological communities of high conservation potential	13.1 Extent of vegetation type or marine habitat type in protected areas
Increase in knowledge of biological diversity			14 Proportion of bioregions covered by biological surveys 24.1 Number of species described per reporting cycle 24.2 Number of taxonomists involved per reporting cycle 24.3 Amount of funding for taxonomy 24.4 Number of research programs into surrogates 24.5 Number of research programs into the role of biological diversity in ecological processes 24.6 Number of long-term ecological monitoring sites 24.7 Percentage of budgets spent on conservation
Involving the community in conservation			24.8 Amount of indigenous ethnobiological knowledge 25.1 Local government management of biological diversity 25.2 Involvement of community groups in conservation
Australia's international obligations			26 Australia's international role in conservation

Key Indicators

Key indicators have been selected and recommended using the Pressure–Condition–Response model. For some themes, such as atmosphere, this model lends itself to an issue-by-issue approach, whereby indicators of pressure, condition and response are developed for each issue. Such an approach is not possible for biological diversity because of the complexity of ecological systems, the strong links between the principal components of biological diversity, and the multiple causes of decline in biological diversity.

The approach taken here has been to identify the main pressures on biological diversity, the main components of the condition of biological diversity, and the principal responses to perceived problems or potential problems. Indicators were then identified against each of these.

Indicators of pressures on biological diversity

Pressure indicators equate to the threatening processes set out in the *National Strategy for the Conservation of Australia's Biological Diversity* and *Australian: State of the Environment 1996* (SoE Advisory Council 1996). Potential indicators of processes and activities (pressures) which have, or may have, significant adverse impacts on the conservation and sustainable use of biological diversity are described below. Where appropriate, the indicators are grouped under the relevant issue raised in the National Strategy or the State of the Environment Report.

Pressure: Human population growth, density and demand

Although not identified as an issue in the National Strategy for the Conservation of Australia's Biological Diversity, *Australia: State of the Environment 1996* (SoE Advisory Council 1996) identified the increasing human population and its demands on natural resources, its affluence and technology as the overarching threat to biological diversity. This is manifest through habitat destruction and modification and a range of other threatening processes. As stated succinctly in Australian Bureau of Statistics (1996): "To understand the human impact on the Australian environment, it is necessary to know how many people live here, and how they are distributed across the continent."

Indicators are needed for this overarching pressure as well as for the various threatening processes which flow from human demands on natural resources.

Indicator 1.1: Human population distribution and density

This is an indicator which is monitored by the Australian Bureau of Statistics for all jurisdictions and is operational now.

Description

Distribution and density of human population expressed as numbers per unit area.

Rationale

See introductory remarks for "Pressure: Human population growth, density and demand".

This indicator reveals where the greatest direct pressures related to human population density (e.g. urban development, transport etc) are manifest. It met 10 of the15 selection criteria for indicators (Table 2).

Analysis and interpretation

The areas of highest concentration of humans are those where the most extreme direct point pressures are exerted on biological diversity terrestrially and in adjacent marine areas (see Australian Bureau of Statistics 1996, pp. 229–238).

Monitoring design and strategy

The Australian Bureau of Statistics conducts censuses of the Australian population every 5 years. Data are collected by units called Census Collection Districts which consist of 200–300 dwellings. There are 30 000 Census Collection Districts in Australia, and these can be aggregated into 1346 Statistical Local Areas.

The Australian Bureau of Statistics has a well-established protocol for collection and expression of data and holds data for the entire Australian population going back to the early 1960s.

Reporting scale

Continental by Statistical Local Area and by IBRA.

Outputs

Map showing population distribution at a continental scale with dots representing 1000 people (see Australian Bureau of Statistics 1996, Fig. 8.1.7). This can also be illustrated by population densities in IBRA regions, with different colours representing different densities (see Australian Bureau of Statistics 1996, Fig. 8.1.15).

Data sources

The Australian Bureau of Statistics collects and analyses population data (see Australian Bureau of Statistics 1996, pp. 229–238) and can customise analyses for reporting at a range of scales, including IBRA.

Links to other indicators

This indicator, together with 1.2 "Change in human population density", provides the best information on the overarching pressures on biological diversity from the human population.

INDICATOR 1.2: CHANGE IN HUMAN POPULATION DENSITY

This is an indicator which is monitored by the Australian Bureau of Statistics for all jurisdictions and is operational now.

Description

Change in human population density.

Rationale

See introductory remarks for "Pressure: Human population growth, density and demand".

This indicator is necessary to show the regions of highest growth rate which equate to increases in pressures on biological diversity. It also shows regions where density is falling — although this does not necessarily equate to lessening pressures on biological diversity. On the contrary, it may indicate environmental problems. As Australian Bureau of Statistics (1996) pointed out: "local population decline may sometimes indicate that an area cannot support its population because of environmental or economic problems".

This indicator met 11 of the 15 selection criteria for indicators (Table 2).

Analysis and interpretation

See Australian Bureau of Statistics 1996, pp. 229–238.

Monitoring design and strategy

The Australian Bureau of Statistics conducts censuses of the Australian population every 5 years. Data are collected by units called Census Collection Districts which consist of 200–300 dwellings. There are 30 000 Census Collection Districts in Australia, and these can be aggregated into 1346 Statistical Local Areas.

The Australian Bureau of Statistics has a well-established protocol for collection and expression of data and holds data for the entire Australian population going back to the early 1960s.

Reporting scale

Continental by Statistical Local Area and by IBRA.

Outputs

Map showing change in population density by IBRA regions (see Australian Bureau of Statistics 1996, Fig. 8.1.8).

Data sources

The Australian Bureau of Statistics collects and analyses population data (see Australian Bureau of Statistics 1996, pp. 229–238), and can customise analyses for reporting at a range of scales, including IBRA.

Links to other indicators

This indicator, together with 1.1 "Human population distribution", provides the best information on the overarching pressures on biological diversity from the human population.

Pressure: Clearing/fragmentation/degradation of native vegetation or marine habitat

INDICATOR 2.1: EXTENT AND RATE OF CLEARING, OR MAJOR MODIFICATION, OF NATURAL VEGETATION OR MARINE HABITAT

This is an indicator which should be monitored across all jurisdictions and could become operational relatively easily, depending upon the availability of data and funding.

Description

Rate of clearing or major modification — classified by agent or sector such as agriculture, forestry, mining, transport, tourism, urbanisation etc. or agent of habitat modification such as the creation of ponded pastures, draining of wetlands, channelisation of watercourses, trawling, dredging etc. — expressed in hectares per annum of native vegetation types per IBRA region or marine habitat per IMCRA region.

Rationale

Clearing or extensive modification of native vegetation or marine habitat, usually because of change in land or resource use, causes local species extirpations and reduces the total area of habitat available to species that are still extant, increasing the risk of local extirpation. Global extinction may be the final result if clearing or habitat modification continues unchecked. This has been, and still is, the major human activity causing a decline in biological diversity (SoE Advisory Council 1996).

This indicator met 14 of the 15 selection criteria for indicators (Table 2).

Analysis and interpretation

Vegetation types should be taken from a new national classification system that is hierarchical and nested within IBRA regions (see discussion on "Vegetation types" above and "Research and development needs" below). If reporting is to occur before this new classification is developed, the vegetation types should be taken from the map of terrestrial vegetation compiled by J.A. Carnahan and published in Volume 6 of the Atlas of Australian Resources (Commonwealth of Australia 1990).

Trawling can cause major habitat changes in areas where the seabed supports large sessile animals such as sponges and fan corals. Extremely limited research has been undertaken to date on the extent of these structured seabeds in Australian waters, although studies on the North West Shelf by CSIRO have shown significant changes in the fauna in areas following trawling. Much of Australia's prawn trawling takes place over soft (muddy or sandy) seabed, and the extent of the impact on the fauna of these bottoms is not known.

The extent and rate of clearing and modification of native vegetation, and the areas affected by trawling and dredging, should be tabulated and mapped. This can be done for terrestrial vegetation with remote sensing (see Graetz *et al.* 1995; CSIRO 1997). The extent of trawling can be obtained from State and Commonwealth fisheries management agencies. As the extent of impact is related to the intensity of trawling, the data should be aggregated to show the intensity. This monitoring program is one of the most important for state of the environment reporting on biological diversity. It will show which regions, and which vegetation or marine habitat types within those regions, are at greatest risk of losing biological diversity, and which are at least risk. This will enable the identification of regions, and vegetation types and marine habitat types within those regions, which should be targeted for remedial action and where most effort is needed to monitor response indicators.

Monitoring design and strategy

1. Maps of vegetation types and marine habitat types (both of which need to be developed) should be digitised, and the different types listed for tabulating the extent of clearing and for monitoring the rate of clearing or modification of communities at local government scales. These data should then be aggregated up for region-wide reporting on vegetation types and marine habitat types at the national scale. If this proves to be prohibitively expensive, areas where rapid clearing is known to be taking place can be targeted using a combination of remote sensing, aerial photographs and administrative records to obtain estimates of clearing rates. It will, however, be difficult to assign different rates to different vegetation types consistently, because existing classifications vary. If reporting on the national extent of remaining native vegetation is required in the interim, compare the two maps (native vegetation types and existing vegetation, 1980s) in Commonwealth of Australia (1990).

2. A correlation between satellite image signatures and/or aerial photograph patterns and different vegetation types and intertidal and shallow marine vegetation habitat types — and, if possible, communities within these types — should be established. Graetz *et al.* (1995) have done this for 34 land cover types across Australia. Remote sensing at the TM scale has the potential to map existing woody vegetation, clearing and re-vegetation. However, new research may be required to break this down into vegetation types, intertidal and shallow marine vegetation habitat types and communities, and to establish links between image signatures and levels of habitat modification. Ground assessment will almost

certainly be required (see Campbell and Wallace 1998). Existing geographic information system (GIS) software could be used to calculate the area of vegetation types cleared or percentage of intertidal and shallow marine vegetation habitat modified. This process cannot be carried out for marine seabed types at present because these cannot be mapped using remote sensing.

3. The change in extent and modification of each type should be measured. Time scales should vary — from 3 to 5 years nationally to coincide with national state of the environment reporting cycles, to annually for areas currently being cleared or modified.

4. All land and coastal marine areas within Australia's jurisdiction should be covered by this indicator.

5. In marine habitats, extent of trawling or dredging on benthic communities should be monitored by marine habitat type as far as possible and expressed as absolute area and percentage of marine region affected. Because of the variable extent of trawling by area and the cumulative impact of trawling, the data should be expressed as areas trawled fewer than ten times per year and areas trawled more than ten times per year.

6. Benchmarks. A comparison of existing vegetation types with the maps of vegetation types pre-1750 (for vegetation in the interim, the maps in Commonwealth of Australia 1990) will determine the extent of clearing and modification since European settlement. Existing vegetation, by vegetation type within IBRA region, and eventually also existing marine habitat type within IMCRA region, will become the new benchmark for subsequent state of the environment reporting.

Reporting scale

From local government areas to the continental scale. For national state of the environment purposes, IBRA and IMCRA regions are the appropriate scales.

Outputs

Tables, maps and trend graphs of change in vegetation or habitat type by agent of change, and advice based on empirical data for planners and policy makers.

Data sources

Remotely sensed imagery (Landsat TM and aerial photographs) is held by State and Territory land management agencies, Environment Australia, CSIRO Earth Observation Centre and the Leeuwin Centre in Western Australia. The Australian Fisheries Management Authority and most State fisheries agencies hold data on the extent and intensity of trawling by area. The Bureau of Resource Sciences (BRS) is working jointly with the States on change in land cover and has data on change in land cover between 1990 and 1995 for the intensive agricultural regions of Australia, which amount to about 15% of the land area.

Links to other indicators

This indicator is closely linked to Indicator 2.2 "Location and configuration of remnant vegetation and marine habitat". Both of these are required to show the distribution and extent of change of vegetation types and marine habitats. The indicator is also linked to 11.1 "Ecosystem diversity", 11.2 "Number and extent of ecological communities of high conservation value", 13.1 "Extent of each vegetation and marine habitat type incorporated within protected areas", 18.1 "Area of clearing officially permitted", Inland Waters No. 6.5 "Habitat loss", Inland Waters No. 5.3 "Catchment clearance" (see Fairweather and Napier 1998 for details), Land No. 2.5 "Extent of forest ecosystem thinned and open", Land No. 2.2 "Percentage of each IBRA region lost to development relative to percent already affected by native vegetation loss (see Hamblin 1998 for details), Estuaries and the Sea No. 4.5 "Trawl fishing areas clearance" (see Ward *et al.* 1998 for details), and the Montreal Process Indicator 3.3a "Area and percent of forest affected by processes or agents beyond the range of historic variation" (Montreal Process Implementation Group 1997).

Indicator 2.2: Location and configuration or fragmentation of remnant vegetation and marine habitat

This is an indicator which should be monitored across all jurisdictions and could become operational relatively easily, depending on data availability and funding.

Description

The geographic location of remnants of native vegetation and untrawled marine habitat types, by type, and the ratio of total length of edges of these remnants to area.

Rationale

Fragmentation of natural habitat due to clearing and other modifying practices disrupts ecological processes such as nutrient and energy cycling, creates sub-populations of species and isolates those sub-populations from one another. There is widespread agreement among scientists that this isolation may lead to the extinction of species. For species which survive fragmentation of their habitat, average population size is smaller and population variability is increased, thus increasing the risk of extinction due to unpredictable environmental and/or demographic fluctuations.

This indicator met 14 of the 15 selection criteria for indicators (Table 2).

Analysis and interpretation

Analysis should be carried out by mapping existing habitat remnants, calculating the degree of fragmentation and monitoring changes in these two variables. The greater the degree of fragmentation, the greater the risk to the biota dependent on the vegetation or marine habitat type. Continental-level fragmentation indices have been investigated recently by the BRS. The use of satellite imagery has been shown to be feasible for estimating the extent of fragmentation. Monitoring changes in the indices between years is technically feasible, but the interpretation of the indices is still under investigation and this investigation should be completed.

Monitoring design and strategy

Using the monitoring design for 2.1 "Extent and rate of clearing, or major modification, of natural vegetation", above, the remnants of vegetation types or marine habitat types should be mapped and the degree of fragmentation measured. The change in degree of fragmentation should be monitored by measuring the change, over time, in the length of edges of vegetation remnants or marine habitat remnants in relation to area or some variant of this. The current BRS study should suggest appropriate measures. In regions such as the Avon Wheatbelt, one of the IBRA regions in the intensively cleared wheat–sheep zone, it is impossible at present to measure fragmentation by examining all remnants. Therefore, some sampling must be undertaken to measure fragmentation using representative areas, with the indicator developed from those representative areas. However, remote sensing at the TM scale has the potential to provide maps of existing woody vegetation, clearing and revegetation, and these are being produced nationally for 1990 and 1995. Existing geographic information software could be used to map vegetation remnants, calculate sizes and calculate the ratios of edge length to area. To do this by vegetation type may require new research to establish correlations between remotely sensed signatures and those types (see above).

This approach could be used for seagrasses, but it is difficult to apply to other marine habitats. It is not possible to map the natural distribution of seabeds carrying large sessile organisms such as sponges and corals. Their distribution is extremely patchy. However, it is known that trawling can modify or remove these organisms. So it is feasible to compare areas that are trawled frequently (for example, more than ten times a year) with areas subjected to little or no trawling, and to use this proportion as an indicator of the extent to which the seabed is impacted by trawling. Mangroves have a largely linear distribution which is fragmented because of natural features. In many areas it may be feasible to record the length of estuary and coastline fringed by mangrove and develop a measure of change. Intertidal habitats such as saltmarsh are subject to pressures such as conversion to ponded pastures, and these should be monitored for fragmentation. It is difficult to see the application of this indicator to sub-tidal marine habitats.

The benchmark would be the current locations of remnants and the current degree of fragmentation.

Reporting scale

From local government areas to the continental scale. For national state of the environment reporting purposes, IBRA and IMCRA regions are the appropriate scale.

Outputs

Tables, maps, trend graphs and advice based on empirical data for planners and policy makers.

Data sources

Remotely sensed imagery is held by a range of Commonwealth, State and Territory land management agencies (e.g. NT Department of Lands, Planning and Environment; SA Department of Environment and Natural Resources; Victorian Department of Natural Resources and Environment; NSW National Parks and Wildlife Service; Murray–Darling Basin Commission, Environment Australia, CSIRO Earth Observation Centre and the Leeuwin Centre in WA. Some agencies have used this imagery to plot remnant vegetation. For example, Agriculture WA has data on the distribution of remnant vegetation based on aerial photography on a geographic information system for many shires in the wheat–sheep zone. However, these are not available by vegetation type. While maps are produced of remnant vegetation and percentage remaining, these do not provide an index of fragmentation. This database is currently being upgraded using TM satellite imagery. The WA Department of Conservation and Land Management holds data on vegetation in the forests of the south-west.

Data on marine vegetation types (seagrasses, mangroves and macroalgae) are held by CSIRO Division of Marine Research for the southern half of WA, SA and Tasmania, and are being collected for NSW. These are prepared from aerial photography, and ground-truthed by diving. These data are not presently held on a geographic information system. The Division also holds detailed information on seagrass distribution and seabed type for Torres Strait. Data for this are held on a geographic information system. Further research is required to determine ways of effectively monitoring subtidal marine habitats. The Australian Fisheries Management Authority and most State fisheries agencies hold data on the extent and intensity of trawling by area. The NT Department of Lands Planning and Environment has marine habitat information in its Coastal Resource Atlas, and in WA a Coastal Resource Atlas is being developed by the Departments of Transport, Environment, Land Administration and Fisheries, and the Australian Maritime Safety Authority.

Links to other indicators

This indicator is closely linked to 2.1 "Extent and rate of clearing, or major modification, of natural vegetation or marine habitat". Both of these are required to show the distribution and extent of change of vegetation types and marine habitats. The indicator is also linked to 11.1 "Ecosystem diversity", 11.2 "Number and extent of ecological communities of high conservation value", 13.1 "Extent of each vegetation and marine habitat type incorporated within protected areas", 18.1 "Area of clearing officially permitted" and the Montreal Process Indicator 1.1e "Fragmentation of forest types" (Montreal Process Implementation Group 1997).

Pressure: Alien or exotic species

INDICATOR 3.1: RATE OF EXTENSION OF EXOTIC SPECIES INTO IBRA

This is an indicator which should be monitored across all jurisdictions. [Land Indicator No. 4.1 (see Hamblin 1998 for details)]

INDICATOR 3.2: PEST NUMBERS

[Estuaries and the Sea No. 3.11 "The number and identity of each introduced species declared as a pest in each estuary catchment and IMCRA region" (see Ward *et al*. 1998 for details)]. This indicator also includes Inland Waters No. 6.6 "Exotic flora/fauna" (see Fairweather and Napier 1998 for details).

These indicators have been developed as part of the Land, Estuaries and the Sea, and Inland Waters themes.

These indicators are important for biological diversity because Australia has been colonised by a range of novel (alien or exotic) species which, without their natural competitors, predators, parasites and diseases, have affected biological diversity in a variety of ways — from the more conspicuous, such as predation by foxes, cats and some marine organisms and overgrazing by goats and rabbits, to the less obvious, such as changing habitat conditions through competition for food or space and forcing indigenous species into marginal habitat.

Pressure: Genetically modified organisms

INDICATOR 4.1: DISTRIBUTION AND ABUNDANCE OF GENETICALLY MODIFIED ORGANISMS

Description

The distribution and abundance of genetically modified organisms which have been released into the Australian environment.

Rationale

The technology for genetically engineering organisms is now available, and the possibility that genetically modified plants, microorganisms and even animals may be released into the wild is real. Their likely impact on biological diversity is not yet known, although it is a reasonable assumption that at least some will behave like invasive alien species.

A more precise indicator of the impact of genetically modified organisms would be the number of wild relatives into which genes have crossed, or which have a close enough relationship for cross-breeding to be feasible. At this stage, there is insufficient knowledge to develop such an indicator. In the meantime, distribution and abundance should be monitored in order to track the spread and population size of genetically modified organisms, as an indicator of their likely impact on natural biological diversity.

This indicator met only four of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

Monitoring approvals for the use of genetically modified organisms will enable a list to be maintained, including information on genetic structure. Monitoring any releases will allow an assessment of their impact on biological diversity.

Monitoring design and strategy

The numbers of approvals for research into, and for commercial exploitation of, genetically modified organisms should be monitored. For every release of genetically modified organisms, the rate of change in distribution and abundance by IBRA or IMCRA region should be monitored.

Reporting scale

Reporting should be at all scales from the local to the national.

Outputs

Lists can be reported as they are updated. Monitoring of releases should be reported as maps of distribution and abundance by vegetation type by IBRA region and habitat type by IMCRA region.

Data sources

Data on genetically modified organisms are coordinated nationally by the Genetic Manipulation Advisory Committee.

Links to other indicators

This indicator links to 19.1 "Number of management plans for exotic/alien/genetically modified organisms", 19.2 "Number of research programs for exotic/alien/genetically modified organisms", and 19.3 "Amount of funding for research and control of exotic/alien/genetically modified organisms".

Pressure: Pollution

Indicator 5: Pollution

Indicators of pollution pressure are important because pollution has the potential to impact severely on elements of biological diversity. The following indicators of pollution pressure have been developed: Land No. 6.1 "Total immobile contaminant load per land area", Land Resources No. 6.2 "Dollar value of pesticides sold per land use", Land Resources No. 6.3 "Rate of pesticide resistance onset in target species" (see Hamblin in press for details), Inland Waters No. 3.5 "Pesticide usage and exposure", Inland Waters No. 3.6 "Pollution point sources" (see Fairweather and Napier 1998 for details), Estuaries and the Sea No. 7.5 "Coastal discharges", and Estuaries and the Sea No. 7.15 "Shipping accidents" (see Ward *et al*. 1998 for details). A response indicator for reporting on biological diversity is described below.

Pressure: Altered fire regimes

Indicator 6: Areal extent of altered fire regimes

Description

The extent and proportion of vegetation types burnt by fire regimes altered by Europeans, broken down according to fire frequency and seasonality.

Rationale

Australian biological diversity has evolved in the presence of fire, except for relatively small areas such as those containing rainforest, and even there the limits of distribution are controlled largely by fire with big shifts over geological time. Altered fire regimes — for example, so-called cool burns for fuel reduction or active fire suppression — impose disturbances which are not yet fully understood but have the potential to alter biological diversity.

This indicator met nine of the 15 criteria for selection of indicators.

Analysis and interpretation

The monitoring program should record the extent of altered fire frequency and seasonality and, therefore, the extent of a practice which has the potential to degrade biological diversity in a less obvious way than, for example, clearing and fragmentation. The baseline should ideally be pre-European settlement fire regimes. However, this is open to considerable debate in some vegetation types (e.g. production forests) and is a major research issue. An alternative would be to monitor, by vegetation community, the time since fire; this would allow successional stages to be determined so that planning could aim to retain the range of successional stages in each community.

Monitoring design and strategy

The extent, frequency, seasonality and impact of fire by vegetation types should be monitored by:

1. using remote sensing data. The WA Firewatch program is conducted by the WA Department of Land Administration, which produces maps of areas burnt at 10-day intervals for the savannas of northern WA and the NT. This uses AVHRR data at a pixel size of 1 km. This is suitable for the extensive fires common in northern Australia; however, the smaller areas burnt in southern Australia require the higher spatial resolution available from Landsat MSS (80 m by 80 m) or TM (30 m by 30 m). The cost of data and processing make this unrealistic for anything but sample areas or regions.

2. using records maintained by State and Territory fire management agencies.

Reporting scale

From the local government scale to the continental scale by IBRA region. In WA, the Department of Land Administration has the capacity to produce maps showing frequency, extent and seasonality of fires by individual pastoral property, shire or region for the northern part of WA and the NT.

Outputs

Publication of tables and maps showing extent, frequency and seasonality by vegetation type. This may also be expressed as percentage of region experiencing fire at yearly increments — e.g. percentage burnt annually, within the previous 5 years etc.

Data sources

Management plans, databases and records of agencies using fire for management (e.g. NT Parks and Wildlife Commission, WA Department of Conservation and Land Management, Victorian Department of Natural Resources and Environment and Country Fire Authority, NSW National Parks and Wildlife Service) and remotely sensed imagery held by various agencies (e.g. WA Department of Land Administration Remote Sensing Branch monitors and reports on the extent, frequency and seasonality of fires throughout WA). Agencies generally only monitor fires over the area under their management, and there is no centralised source of data.

Links to other indicators

This indicator is linked to the response indicator 21 "Reducing the impacts of altered fire regimes" and the Montreal Process Indicator No. 3.1a "Area and percent of forest affected by processes or agents beyond the range of historic variation, e.g. by insects, disease, competition from exotic species, fire, storm, land clearance, permanent flooding, salination and domestic animals" (Montreal Process Implementation Group 1997).

Pressure: Human-induced climate change

Indicator 7: Human-induced climate change

Indicators of human-induced climate change are important because climate change has the potential to impact on elements of biological diversity. Indicators of climate change have been developed as part of the consultancy on environmental indicators of atmosphere for national state of the environment reporting.

A response indicator for reporting on biological diversity (22 "Minimising the potential impacts of human induced climate change on biological diversity") is described below.

Pressure: Harvesting

Indicators 8.1–8.4: Species and numbers of species taken from the wild, as commercial harvests, during culling operations or recreationally.

Description

8.1 Lists and numbers of organisms being trafficked and legally exported.

8.2 The number of permits requested and issued for legal collecting or harvesting, by venture, by taxon and vegetation type within IBRA regions on land or by IMCRA region.

8.3 The proportion of numbers collected over the size of the reproducing population by species for the major fished species.

8.4 Ratios of bycatch to target species in trawl fisheries and amount of material discarded at sea. Numbers of individuals of endangered or threatened species (e.g. turtles, dugong and albatross) killed by commercial fishing operations within Australian waters each year.

Rationale

The extent of the removal of indigenous organisms from the wild is a measure of the pressure of such activities on biological diversity. Harvesting, culling and recreational take-off — including plant harvesting and seed collection — reduces population sizes and may change the demographic characteristics of populations, affecting fecundity and rates of recruitment.

Analysis and interpretation

Monitoring harvesting and culling operations, bycatch in the fishing industry and recreational take will enable management agencies to assess the impacts of these activities on elements of biological diversity and recommend planning and policy measures accordingly. Decrease in catch for the same unit of effort may indicate problems with target taxa which should prompt some response from management agencies.

Some recreational impacts, eg., duck hunting, are already monitored, though others such as fishing — particularly recreational fishing — present a challenge, especially for fisheries without any licensing. This problem can be overcome by correctly structured surveys.

Monitoring design and strategy

8.1 Data on the identity and numbers of organisms being moved from the collection point to another location, including interstate and overseas, should be collected. Note that organisms being moved to points outside their range have the capacity, if released, to become pressures on other elements of biological diversity. This indicator met 12 of the 15 criteria for the selection of indicators (Table 2).

8.2 Data on number of permits requested and issued for legal collecting or harvesting should be obtained from the authorities responsible for licensing. Data on catches of commercially fished species should be obtained from the relevant State and Commonwealth licensing agencies, and by means of surveys for recreationally fished species. This indicator met 12 of the 15 criteria for the selection of indicators (Table 2).

8.3 Estimates of the reproducing population should be made for any species being exploited for whatever reason. Methods for collecting these estimates will depend on species, life histories etc. Data on numbers collected should be collected from those involved in the harvesting activities. This indicator met 10 of the 15 criteria for the selection of indicators (Table 2).

8.4 Data on bycatch should be monitored by weight of catch in relation to weight of species being harvested by trawling and by numbers killed in the case of endangered and threatened species. This requires monitoring systems to be set up for commercial and recreational fishing operations. This indicator met eight of the 15 criteria for the selection of indicators (Table 2).

Reporting scale

On the land, by vegetation type within IBRA regions. In coastal and marine environments, by IMCRA region.

Outputs

Tables showing the impact of harvesting or bycatch, by species, by region. For example, number of albatross killed by longline fishing per year in waters under Australian control.

Data sources

Data are held by State and Territory natural resource management agencies and agencies responsible for the issue of licences and export permits for native biota (e.g. NT Department of Primary Industry and Fisheries and Parks and Wildlife Commission, Qld Departments of Environment and Natural Resources, WA Departments of Conservation and Land Management and Fisheries, and Agriculture WA, Victorian Department of Natural Resources and Environment and Marine and Freshwater Resources Institute). The Australian Fisheries Management Authority collects bycatch and total catch data for Commonwealth fisheries. The Bureau of Resource Sciences also collects fisheries data.

Links to other indicators

This indicator links with the response indicators 17.1 "Number of management plans for ecologically sustainable harvesting", 17.2 "Effectiveness of bycatch controls", Estuaries and the Sea Indicators No. 4.3 "Fish stocks" and 4.5 "Trawl fishing area" (see Ward *et al*. 1998 for details) and Montreal Process Indicator 2.1d "Annual removal of wood products compared to the volume determined to be sustainable" (Montreal Process Implementation Group 1997).

Indicators of condition of biological diversity

This section describes potential indicators of state (or condition) of biological diversity, covering: genomes and genes of environmental, social, scientific or economic importance; ecosystems and habitats of high diversity or high endemism; and areas that have large numbers of threatened or rare species or communities, are required by migratory species, are involved with key evolutionary or other biological processes, or are important for other social, economic, cultural or scientific reasons.

Condition: Condition of genetic diversity

This section on indicators of genetic diversity for national state of the environment reporting, together with much of the section on "Target taxa" earlier in this report, has been taken from a consultancy report on indicators of genetic diversity coordinated by Dr Tony Brown and Dr Andrew Young and contributed to by Dr Jeremy Burdon, Dr Les Christidis, Dr Geoff Clarke, Dr David Coates and Dr Bill Sherwin, and reviewed by Dr Craig Moritz and Dr Ross Crozier (Brown *et al.* 1997). The material has been edited by Denis Saunders to follow the format of the main report on indicators of biological diversity.

Introduction

Genetic diversity is the variation within and between related genes present in different individuals or different species of organisms. Levels and patterns of genetic diversity are the result of both micro- and macro-evolutionary processes, and as such are a within-species reflection of the integrity and functioning of evolutionary and ecosystem processes.

Genetic diversity is essential in the maintenance of biological diversity because the ability of individuals to survive and reproduce (i.e. their fitness) depends largely on their genotype. Individuals carrying more than one form (allele) of a particular gene are known as heterozygotes and are on average "fitter" than individuals carrying identical copies for that gene (homozygotes), particularly when this effect is summed over the many thousands of genes in the genome of a single individual. In addition, certain alleles of particular genes are deleterious in their effect on fitness when homozygous, whereas heterozygotes can often mask this deleterious effect if they also carry non-deleterious alleles of these genes.

Genetic diversity can enhance population fitness because populations that harbour a range of genotypes are, on average, able to occupy a broader range of habitats than genetically uniform populations. This is because the products of genes and gene interactions enable an individual to survive and reproduce under a limited set of environmental conditions. Products from one form of a gene may adapt an individual to one set of environmental conditions better than the products of another form of the same gene, which in turn, is better adapted to a different environment.

Evolution is fully dependent on the level of genetic variation within a species. Because of genetic differences among individuals within a variable population, particular individuals will be favoured when environmental conditions change. Populations or species that are depauperate in genetic diversity are less able to respond to environmental change than their more variable counterparts, and are thus more prone to extinction.

Genetic diversity also has utilitarian value. The variety of animals and plants that humans use every day reflects underlying genetic diversity. Plant and animal breeders have manipulated genetic diversity within populations and species to breed an enormous number of different breeds and varieties (genetic forms) for a wide range of environmental conditions.

Genetic diversity for state of the environment reporting differs from the species and ecosystem levels of biological diversity in several ways. First, it is frequently cryptic, unlike species or ecosystem level diversity, and requires experimental effort to detect. Second, genetic diversity expresses itself at several structural levels — those of the individual, subpopulation, population, and metapopulation. Third, genetic diversity is not a static resource; it is more dynamic both spatially and temporally than either species or ecosystem diversity. In sexually reproducing organisms, individuals are genetically unique and are not the object of conservation *per se*.

The amount and distribution of genetic diversity within a species is determined by the interacting effects of five main evolutionary processes: mutation, selection, random genetic drift, migration, and mating and genetic recombination. Pressures on biological diversity at the gene level are due to changes in the environment (e.g. clearing, fragmentation, pollution) that affect these processes and, through this, influence genetic diversity.

Given the dynamic nature of the resource, the goal of conserving "appropriate" genetic diversity is best achieved not by focusing on maintenance of the genes and genotypes that currently exist within a species, but by trying to prevent drastic alteration in the pace and direction of these micro-evolutionary processes.

What sorts of indicators can be used?

Indicators of the condition of genetic diversity are those parameters that are informative as to the state of evolutionary processes. Useful information can be drawn not just from direct measures of these processes, but also from population characteristics which are likely to affect particular processes and from measures of diversity which reflect the action of these processes. For example, three indicators that monitor effects of fragmentation on mating processes would be: population size, which can affect mating patterns by restricting the availability of mates; mating parameters themselves such as outcrossing rate; and individual genetic variation, which is directly affected by mating events.

Obviously, these three different indicators have different information contents. Direct measurements of mating system parameters, such as outcrossing rate, may be the most informative at a particular point in time. However, these involve the use of sophisticated marker technologies and are expensive both in time and cost. Using population size as an indicator of what is happening to the mating process is appealing because it is readily measured and so can be monitored broadly. However, in the absence of good data on how population size relates to effects on mating, it provides less information. Individual genetic variation is easier to monitor than mating itself, and has more genetic reality to it than population size, being directly influenced by mating. But it is also influenced by other processes such as genetic drift, and is likely to respond more slowly to a change in mating than would a direct mating system parameter like outcrossing rate. Therefore it is likely to be less sensitive. Conversely, this slow response may be useful if it allows integration of effects over time. The choice of appropriate indicators to use is a trade-off between information content, scale of monitoring and associated costs.

Interpretation of indicators

Interpretation of changes in measures for different indicators is complicated in three ways. The first relates to understanding what a particular measure reflects in terms of evolutionary processes; indicators and their measures will often be affected by several processes. Secondly, it is difficult to know what amount of change in an indicator is significant in terms of reflecting a negative or positive change in genetic biodiversity. For example, how many alleles are enough? How much inbreeding can be tolerated before populations become unviable? This second point concerns the issue of baselines, or reference points. The third complication concerns how to go about interpretation of multiple indicators and their measures when they appear to give conflicting results.

Baselines

In the simplest form for state of the environment reporting, values of measures taken at the beginning of the reporting period can serve as baselines against which future changes can be measured. This makes the assumption that the current state of genetic biodiversity is adequate and that the current dynamics of evolutionary processes are stable. Both of these assumptions are unlikely to be true.

A second approach is to use data from studies which have already been conducted to provide generalised baselines for different indicators for the different groups of target taxa. For example, the large amount of allozyme data available on both plant and animal species allows some expectations to be erected regarding the levels of measures of genetic diversity such as heterozygosity or allelic richness within populations. The advantage of this approach is that the significance of a deviation from these expectations can be expressed quantitatively in terms of its magnitude relative to the variance associated with these expectations. However, this approach is limited to target taxa for which sufficient studies have already been conducted and there are large gaps here. For example, there is good information for some trees and mammals, but little information exists for insects, non-vascular plants, fungi or bacteria.

A third approach is to limit target taxa to those for which it is still possible to gather information from undisturbed populations. These populations can be monitored as baselines, while disturbed populations can be monitored simultaneously to check effects of ongoing pressures. This approach is appealing as it also establishes baselines for expected temporal variation in indicator measures which are generally unavailable.

Conflicts among trends shown by different indicators

In most if not all situations several indicators will be monitored, and for each indicator there may be several measures that are being made. Given this, careful interpretation of the joint behaviour of different indicators and their measures is necessary. When all measures and indicators are performing in the same fashion, interpretation is simplified. Indeed, the joint response of a range of indicators lends credibility to any observed trend. However, it is often likely to be the case that some indicators show changes from one monitoring period to the next while others do not. Even more difficult is if some indicators show trends in one direction, while others show movements in another.

When different indicators of the same evolutionary process apparently conflict, the indicator that most directly reflects that process is the most reliable one. For example, a change in outcrossing rate is a more direct sign of a change in mating than is a change in heterozygosity. Differences in the response of different indicators to a single stress may reflect the different effects that this stress has on different processes. One example is when allelic richness declines as population size is reduced, but heterozygosity is unaffected. This would suggest that the change in population size has increased the amount of random genetic drift in the population, but it has had little effect on mating.

It may also be the case that the same measure of an indicator shows different trends when measured on different marker genes, or quantitative traits. Rather than being a problem, careful choice of marker genes or traits that are thought to be primarily affected by different evolutionary processes can allow these contrasts to provide information about differential effects of the same stress on different processes. Indeed, analysis that compares markers thought to be under strong selection with those thought to be basically neutral may be the only way to examine genetic responses to stress through selection.

INDICATOR 9.1: NUMBER OF SUB-SPECIFIC TAXA

Description

Number of distinct entities (such as subspecies; ecotypes; geographic, morphological, physiological, behavioural or chromosomal races) readily recognisable within a species.

Rationale

Sub-specific (or infraspecific) entities (or taxa) are a useful first approximation of genetic diversity within a species, particularly if they can be named and described or depicted for easy recognition. They provide a possible measure of the level of genetic differentiation within a species and of the pattern of genetic differentiation throughout its range. The number of such variants occurring in an area is relatively insensitive to small changes in genetic structure. However, any loss of infraspecific taxa is likely to indicate a substantial loss of genetic diversity in the species. This indicator is more useful for widely distributed species — particularly if they are rich in such variation, cover a number of biogeographic regions or habitats, and have populations with a disjunct or fragmented distribution.

This indicator met 11 of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

The total number of infraspecific entities in the complete set of selected target species within the target region will provide the initial baseline data. Generally, the number —and therefore the genetic diversity — would decline over time in areas subject to major environmental disturbance. Once the target set and area are delineated, the monitoring of change would be effective in gathering data relatively quickly and cheaply. Changes in the numbers of entities can be compared between regions based on the rate of loss and the proportion of entities lost over a specified time. Recent molecular studies have sometimes revealed discrepancies between putative subspecies boundaries and historical phylogenetically defined units. Such studies serve to caution against uncritical acceptance of this indicator of diversity. Major changes in values should trigger a deeper genetic analysis to determine whether substantial genetic erosion is under way.

Monitoring design and strategy

Infraspecific entities (taxa) may consist of one or more populations unique to a geographic area, habitat type, or zone disjunct from the main species range. This includes outlier populations, island populations and ecotypes.

For each selected area or region, a change in the number of infraspecific entities for a range of target species would be monitored over time. The more species monitored, the more sensitive the indicator. If monitoring includes data on significant decline in numbers of the various entities — beyond simply noting their localised presence or extinction — sensitivity is further increased.

Reporting scale

Results can be reported from the local government level (taxa with localised distributions) to national level (species with Australia-wide distributions).

Outputs

Tables and charts monitoring change in number of infraspecific entities (taxa) within various taxonomic groupings over time.

Data sources

Defining infraspecific entities within the target species will require information from a range of sources. Their initial recognition will be based on current taxonomic knowledge available from museums, herbaria, taxonomists and taxonomic treatments. Further subdivision of subspecific entities will rest on biogeographic, ecological, physiological, genetic or behavioural information from many sources. These include publications in books and journals, reports by government departments, research institutes and universities, and data held by individual scientists and naturalists.

Links to other indicators

Links directly to indicators 9.2 “Population size, number and physical isolation”, 10.1–10.12 “Species diversity, conservation status, economic importance and extent of knowledge”, and 11.1 “Ecosystem diversity”.

Indicator 9.2: Population size, numbers and physical isolation

Description

9.2.1 The numbers of individuals within each population.

9.2.2 The number of discrete populations.

9.2.3 The degree of physical isolation between populations.

Rationale

In general terms, the size and number of individual populations are related to their ability to cope with both random (stochastic) fluctuations in the environment and steady (systematic) long-term change. The frequency distribution of the sizes of individual populations is likely to reflect the way in which genetic variation is partitioned within and among populations, with small populations being at increased risk of loss of alleles, reduced heterozygosity, increased uniformity, enhanced inbreeding or possible extinction. The number of discrete populations and their degree of physical isolation are likely to reflect both the overall genetic diversity of the species and the way in which variation is distributed. Species with widely separated, small populations in which gene-flow is limited or presently non-existent are likely to show declining levels of within-population genetic diversity even while variation at the species level remains relatively constant.

This set of indicators met 12 of the 15 criteria for selection of indicators (Table 2), and provides the simplest and most accessible means of obtaining a broad-scale view of the potential genetic effects of changes in the environment.

Analysis and interpretation

Map data for designated species onto three-dimensional graphs to see relationship between the three indicators. The three indicators, while closely linked, will show a different propensity to change. Most species will fit non-linear relationships (logarithmic or asymptotic — frequently dependent on dispersal mode and efficiency) between change in the indicator and its consequence for the extent and partitioning of underlying genetic variation. As a consequence, much greater significance should be given to changes occurring against a narrow starting base (few, small, geographically isolated populations) than to changes occurring against a broad starting base (many, large, geographically widely dispersed populations). Changes in these indicators should be interpreted as early warnings of potential changes in genetic variation and structure as a consequence of increased drift, genetic erosion, reduced migration and their consequent impacts on genetic processes.

Monitoring design and strategy

Information for these indicators should be collected at regular intervals from the appropriate organisations and agencies working on designated species. For less mobile species (plants and some animals), area measurements of patch sizes will provide a reasonable basis on which to estimate population size. In some of these cases, measuring the extent and rate of vegetation fragmentation will monitor change in status; in other cases monitoring may be possible through existing tagging programs. All other situations will require direct field measurements.

Reporting scale

From local government areas to the IBRA or IMCRA regional scale (and sometimes to the continental scale).

Outputs

Tables, maps, graphs and advice based on empirical data for planners, policy makers, recovery team coordinators etc.

Data sources

Maps of vegetation types and remotely sensed imagery held by State and Territory conservation agencies, departments of lands, Environment Australia and the CSIRO Earth Observation Centre; distribution data held in databases and on collection labels of State, Territory and Commonwealth herbaria, museums and other biological collections; and data on individual species held by Environment Australia and individual researchers in State, Territory and Commonwealth institutions.

Links to other indicators

There are close links to indicators 2.1 "Extent and rate of clearing or major modification of natural vegetation or marine habitat", 2.2 "Location and configuration or fragmentation of remnant vegetation or marine habitat" and 11.1 "Ecosystem diversity".

Indicator 9.3: Environment amplitude of populations

Description

The measure of the extent to which a species maintains occupancy of the full range of habitats in which it naturally occurs, including those it is on record as having occurred in.

Rationale

Virtually all species occur naturally in a range of habitats. In many cases, such habitats differ from one another by specific sets of physical environmental conditions (for example, low oxygen tensions, higher salinity, heavy metal presence, changed pH, different temperatures or insolation levels), to which individual populations of a species may have adapted over many years. Maintaining the species' ability to occupy or colonise the full extent of its range is one mechanism whereby underlying, highly adaptive, genetic variation may be conserved.

This indicator met eight of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

Two monitoring approaches are available: the distribution approach and the physiological approach.

If following the distribution approach, the distribution of designated species should be classified into four categories: widespread, locally common; widespread, locally rare; restricted, locally common; and restricted, locally rare. The way species change between different categories may indicate different genetic responses. For example, a species showing increasing restriction to particularly favourable or protected environments may be potentially indicative of initial losses of genetic variation associated with the species' ability to exist in more marginal habitats. A widespread, locally common species becoming locally rare implies overall reductions in populations sizes, with initial losses in genetic variation at the individual population level (through drift); at first, this may not be accompanied by loss of variation in the species as a whole. In both cases though, movement of species from widespread, locally common towards restricted, locally rare should be regarded as a warning for further assessment.

If following the physiological approach, the number of populations occurring in each distinctly recognisable environment should be tabulated and the rate of loss of populations of each ecotype determined. A significant differential in the rates of loss is indicative of changing ecological amplitude for the species in question. Another option is the measurements of variation in stress resistance, as the genes that control such tolerances may mediate responses to climate change.

Monitoring design and strategy

Two monitoring approaches are available. The first focuses on broad assessments of patterns of distribution. This is the distribution approach, and has the potential to assess relatively rapidly a wide range of species on an IBRA or IMCRA region or continental scale. Monitoring will require estimates of numbers of populations, and of the relative density or numbers of individuals within populations.

The second approach, the physiological approach, is a much more precise instrument focusing on the detailed distribution of individual species. It will be necessary to identify and measure relevant characters of the physical environment in the field at the local level with aggregation of data to IBRA or IMCRA region level.

Reporting scale

For the distribution approach, the IBRA or IMCRA region and continental scales are appropriate. For the physiological approach the local government scale is appropriate, aggregated to the IBRA regions.

Outputs

Tables, diagrams and advice based on historical and current empirical data for planners and local and regional recovery teams.

Data sources

For the distribution approach, distribution data held in databases and on collection labels of State, Territory and Commonwealth herbaria, museums and other biological collections; and data on individual species held by Environment Australia and individual researchers in State, Territory and Commonwealth institutions.

For the physiological approach, high-resolution distributional data from the sources listed above overlain with appropriate high-resolution climatic, terrain and geological mapping data. In many instances, the relevant selective character(s) will have to be identified and measured directly in the field.

INDICATOR 9.4: GENETIC DIVERSITY AT MARKER LOCI WITHIN INDIVIDUALS AND POPULATIONS

Description

This indicator measures genetic diversity as close as is feasible to the DNA level, by screening for differences among the many variants of genes.

Rationale

It is likely that monitoring only at higher levels (species and ecosystem levels) cannot adequately assess biological diversity at the gene level. It is essential, therefore, that gene diversity itself be monitored, and that structured sampling takes account of this need for "ground-truthing" of the generalisations that emerge from monitoring at higher levels.

Similarly, it is not known whether measures of population size and number alone monitor gene diversity sufficiently well. The advantages of measures based directly on marker genes are that they are precisely defined in a genetic sense, they can be summed, and their statistical sampling errors can be specified. This makes them ideal statistics for comparison with other studies and data from other countries.

A steadily expanding range of techniques provides the tools for detecting differences for various kinds of DNA sequence variation. Levels of variation can differ between cytoplasmic and nuclear markers, between protein and DNA sequences, etc. However, the trend is for the same kinds of changes to occur over time for different kinds of markers in response to environmental pressures such as bottlenecks in population size.

This indicator met seven of the 15 criteria for selection of indicators. Considerable research and development would be needed to render it useful for national state of the environment reporting.

Analysis and interpretation

The interpretation of marker gene polymorphism itself has seen a long history of controversy. The variations are at the least measures of the "ancestry" of individuals and populations — of the outcomes of evolutionary processes such as migration, breeding system, bottlenecks of population size etc. It is also possible that some fraction of the variation is directly or indirectly responding to selection pressures. The direct determination of which variants are of adaptive significance requires considerable research effort.

Since a tiny sample is being used to indicate trends on a much broader base, it is necessary in interpretation to ask whether changes in indicator values are restricted to those examples, or are related to some peculiar features of the species, or population, or class of genes, or sampling strategy.

Comparative interpretations have also been the subject of much controversy. The supposed lack of correlation between "neutral" marker variation and variation in ecologically significant characters has received much attention. So too have contrasts between estimates in different species — on the same suite of markers in two different species, or on two different kinds of marker genes. Meta-analyses have, however, shown worthwhile overall trends in, for example, the effect of population size on K or He (see definitions below).

Monitoring design and strategy

It is clearly impossible to census many populations from a large number of species of the biota in all major biomes for their genetic variants. Therefore, this indicator should be monitored in a limited, structured sample of species and populations from a representative set of biomes.

Type studies should ensure that examples of each of the full range of genetic techniques are employed on a reasonable sample of genes.

Various summary measures for allozymes and Restriction Fragment Length Polymorphisms that contribute to this indicator are:

1. K = "allelic richness" or observed number of alleles in a sample (standardised for sample size);

2. Ho = observed heterozygosity of an individual; and

3. He = gene diversity index, or probability that two random copies of a genetic locus will differ.

Both kinds of statistics (K and He) of allelic diversity are needed. K is the more sensitive, and measures the basic raw material for evolution, yet is more susceptible to sampling effects and to alleles occurring at low frequency. He is bounded and converges with sample size. Ho is also a useful indicator of processes such as mating system, or as a predictor of fitness. To interpret the data and sum over taxa etc., an estimate of the proportion of the loci screened that were polymorphic (P) within the total species sample is needed.

In the case of microsatellite loci and DNA sequences, more powerful measures are available that incorporate the degree of phylogenetic similarity among the allelic variants at a locus.

Reporting scale

On a variety of species at all scales from the local to the national.

Outputs

Outputs would be a table of species or population-specific estimates with averages at various levels of the sampling hierarchy and attached sampling errors. Multivariate analyses of such tables would be helpful in indicating major significant trends, or weights for suites of loci.

Data sources

A considerable body of allozyme data now exists for a haphazard sample of the higher animal and plant species of Australia. In addition, molecular data are beginning to accumulate. This published and unpublished information needs to be assembled and codified. From this, a set of species for detailed monitoring could be defined. The existence of prior data will affect species chosen for further monitoring. These data could also provide baselines for assessing the significance of future changes in measure values. A good deal of data will have to be generated de novo.

Condition: Condition of species diversity

Indicators 10.1–10.9: Species diversity, conservation status, economic importance and extent of knowledge of specific levels of biological diversity.

These are national indicators.

Description

10.1 Number of species: actual total only where this is believed to be the final total.

10.2 Estimated number of species; for many groups this figure will be supplied instead of the number of species.

10.3 Number of species formally described.

10.4 Percentage of number of species or estimated number of species that have been formally described.

10.5 Number of subspecies or terminal taxa in Australia expressed as a percentage of the number (or estimated number) of species.

10.6 Number of species endemic to Australia and the areas under its jurisdiction.

10.7 Number and percentage of species presumed extinct, endangered or vulnerable.

10.8 Number and percentage of species of direct economic importance.

10.9 Percentage of species known to be changing in distribution (+/-).

Rationale

The information provided by these indicators will reveal the extent of genetic diversity (number of subspecies), the number and identities (where known) of species, conservation status and economic importance of both terrestrial and marine groups and changes in range. This is the minimum set of indicators necessary for assessment of the state of species diversity.

Biological diversity includes species colonising as a result of human activities (either deliberate introductions as with the rabbit and some species of dung beetle, or species accidentally introduced via agents such as ballast water). Accordingly, introduced species which are free ranging should be accounted for in these indicators; however, indicators associated with them should be expressed separately. Species which have colonised as part of natural range expansions should be accounted for under native species.

Analysis and interpretation

The comparison between the number of species, the estimated number of species and the number formally described will show the difference in knowledge of the various groups which make up species richness. It will also show how those groups we have most information on make up a small part of species diversity. Over successive reports, changes in these figures will indicate a response to this lack of knowledge.

10.1 Number of species. For most vertebrate and vascular plant Orders, this figure will be known. However, for most other taxonomic groups this figure will not be known. Interpretation should take into account the identities of species added to or deleted from the list to makes up Indicator 10.1. Disturbance can lead to the introduction of new species, but if they are not indigenous to the location they may not be regarded as contributing to biological diversity. Similarly, losses of species from the list may be due to changes in knowledge and natural fluctuations in local abundance which do not necessarily represent a decline in biological diversity.

This indicator met ten of the 15 criteria for selection of indicators (Table 2).

10.2 Estimated number of species. For many taxonomic groups, the number of species is not known and so estimates will have to be used. The reliability of these estimates will vary with groups. For example, estimates for arthropods will be more reliable than those for nematodes or bacteria. This indicator met only five of the 15 criteria for selection of indicators (Table 2).

10.3 Number of species formally described. This figure can be given accurately. This indicator met 11 of the 15 criteria for selection of indicators (Table 2).

10.4 Percentage of number of species or estimated number of species that have been formally described. This is an indicator of the extent of knowledge. This indicator will vary in accuracy depending on taxonomic group. Obviously, for those groups where the estimates of total number of species are unreliable this figure will also be unreliable. The lower the percentage, the poorer the knowledge. This indicator met only four of the 15 criteria for selection of indicators (Table 2).

10.5 Number of subspecies or terminal taxa expressed as a percentage of the number (or estimated number) of species. This is an indicator of the genetic diversity of the biota at the national scale (see 9.1 "Number of subspecific taxa"). The assumption is made that the number of subspecies or terminal taxa is a useful surrogate for genetic diversity. This assumption needs to be tested. This figure will only be known for many of the vertebrate and some of the vascular plant Orders. This indicator met 11 of the 15 criteria for selection of indicators (Table 2).

10.6 Number of species endemic to Australia and the areas under its jurisdiction. This in an indicator of the uniqueness of the Australian biota. High endemism implies increased responsibility for protection of those elements of the biota. The reliability of this indicator will vary depending on the extent of knowledge of species and their distributions. Obviously, reliability will be highest for some of the vascular plant and vertebrate Orders and lowest for those groups which are less well studied. This indicator met 9 of the 15 criteria for selection of indicators (Table 2).

10.7 Number and percentage of species presumed extinct, endangered or vulnerable. Conservation status indicates which groups may need special management. Change in these figures over time will provide an indicator of response. This will also show the bias in favour of vertebrates and higher plants. This indicator met 11 of the 15 criteria for selection of indicators (Table 2).

10.8 Number and percentage of species of direct economic importance. This provides an indication of the potential benefit of species retention. Species of economic importance are those which have a role in generating income (e.g. some species of fish or crustacea) or in negatively affecting the generation of income (e.g. some insects or macropods). At present, an extremely small part of the Australian biota is classed as of economic benefit, and some groups such as marine fishes will feature more highly than others. There is also the issue of the provision of ecosystem services, which at present are not accorded any economic value. A major research problem is valuing provision of nutrient cycling, maintenance of water tables, maintenance of the atmosphere, etc. This indicator met three of the 15 criteria for selection of indicators (Table 2).

10.9 Percentage of species known to be changing in distribution (+/-). This indicator could provide an indication of change in status of groupings. However, for many groups the lack of knowledge will mean there are no data available to develop an indicator. This indicator met eight of the 15 criteria for selection of indicators (Table 2).

Monitoring design and strategy

The data for these indicators should be collected at regular intervals from the organisations and agencies which collate them. Obviously, to be effective for state of the environment reporting they should be collected the year before the production of each state of the environment report. Data on distributions depend on surveys, which would only be conducted irregularly and for a limited number of groups. Surveys of birds are undertaken regularly; however, there will be few data for most of the other groups.

Reporting scale

The data needed for this set of indicators are essential for all levels of state of the environment reporting. However, the scale of reporting will differ at the different levels. At the national level, the reporting scale should be by IBRA or IMCRA region, while at the local level it will be by local government area.

Outputs

Table of taxonomic groups (by Order or some other appropriate grouping) showing number of species, number of subspecies, number of species in each conservation grouping and number of species of economic importance. This will be a large table; however, it is necessary to present sufficient detail in order to detect change over time. The table could be summarised by amalgamation and reporting on larger groupings such as vascular plants, non-vascular plants, microorganisms, invertebrates and vertebrates as in the 1996 National State of the Environment Report (SoE Advisory Council 1996).

The first column of the table would consist of:

Taxonomic Group:

subdivided into: native terrestrial
native aquatic
introduced terrestrial
introduced aquatic

Vascular plants: (By Order; as there are nearly 280 Families of plants in Australia, listing by Family would render the table unwieldy)

Non-vascular plants:
- Algae
- Mosses
- Liverworts
- Fungi
- Lichens
- Bryophytes

Microorganisms:
- Protozoa
- Fungi
- Bacteria

Invertebrates: (by Phylum, Class or Order)
- Porifera
- Cnidaria
- Platyhelminths
- Nematoda
- Echinodermata
- Arthropoda (e.g.)
  - Insecta
  - Arachnida
  - Myriapoda
  - Crustacea
- Mollusca (e.g.)
  - Gastropoda
  - Bivalvia
  - Cephalopoda
- Annelida (e.g.)
  - Polychaeta
  - Oligochaeta

Vertebrates: (by Order)

- Fish
- Amphibians
- Reptiles
- Birds (e.g.)
  - Struthioniformes
  - Procellaariiformes
  - Sphenisciformes
  - Podiceiformes
  - Pelicaniformes
  - Ciconiformes
  - Acciptriformes
  - Anseriformes
  - Galliformes
  - Gruiformes
  - Charadriiformes
  - Columbiformes
  - Psittaciformes
  - Cuculiformes
  - Strigiformes
  - Caprimulgiformes
  - Apodiformes
  - Alcediniformes
  - Passeriformes
- Mammals (e.g.)
  - Monotremata
  - Polyprotodonta
  - Diprotodonta
  - Chiroptera
  - Rodentia
  - Pinnipedia
  - Sirenia
  - Cetacea
  - Lagomorpha
  - Carnivora
  - Perissodactyla
  - Artiodactyla
  - Primates

Some of the data could be expressed graphically, providing more impact with some parts of the community. For example, the conservation status of different groups could be shown via a pie chart to highlight those groups, such as mammals, where there is a disproportionately high percentage of endangered taxa.

Similarly, conservation status relative to current knowledge could be shown. Although there is a disproportionately high percentage of endangered mammals, a high number of taxa are unknown. Some indication of the proportion endangered relative to the proportion known would indicate the likely proportion of other taxa endangered, and therefore the problem our lack of knowledge presents.

Data sources

Data on the number of species, estimated number of species, number of species formally described, number of subspecies or terminal taxa, number of endemic species and conservation status of species are held by Environment Australia, State and Territory conservation agencies, museums, universities and CSIRO.

Data on species of economic importance may be more difficult to gather and would almost certainly have to be compiled from a variety of sources, including the Commonwealth Department of Primary Industries and Energy, Environment Australia and State and Territory departments of conservation, agriculture and primary industries.

Birds Australia have data on the changes in the distribution of birds via their Bird Atlas and Australian Bird Count projects.

Links to other indicators

This indicator is linked to 10.10 "Number, distribution and abundance of migratory species by taxon per IBRA and IMCRA region".

Indicator 10.10: Number, distribution and abundance of migratory species by taxon per IBRA or IMCRA region

Description

The number, distribution and abundance of migratory species expressed by taxon in each IBRA or IMCRA region.

Rationale

Australia has an international responsibility to conserve all species, including those which spend part of their life cycle within the area under Australian jurisdiction. Such species may breed in, or around, Australia and spend the non-breeding period elsewhere (e.g. some species of whale), or they may breed elsewhere and spend the non-breeding season in Australia. For example, of the 50 species of wading or shorebirds that regularly occur in Australia, 33 breed outside Australia in central Asia, Siberia or the Arctic zone of North America (SoE Advisory Council 1996). This indicator will highlight those regions which have high concentrations of migratory species. The extent and condition of the habitats which support these species will be indicated by 11.1 "Ecosystem diversity".

This indicator met 11 of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

At present, the only data set on terrestrial animals suitable for this indicator is held by the Royal Australasian Ornithologists Union. It is based on their Bird Atlas project and a review of data relating to sites of importance for wading birds (Watkins *et al.* 1993). These may provide the baseline to allow interpretation of changes in numbers, and number of species, based on future surveys as well as change in the condition of critical habitat. The Australian Fisheries Management Authority carries out ongoing assessments of major pelagic fish species.

Monitoring design and strategy

Surveys would need to be conducted, at regular intervals, of the biota of representative areas of IBRA and IMCRA regions — on a seasonal basis. Such surveys would not to be annual, but could be conducted for at least 2 years, with 5 years between surveys. They could be based on presence/absence data or on some measures of abundance, and condition of habitat should be assessed. Areas of high conservation value for migratory species should be monitored more regularly. This should be feasible in terrestrial and inland water habitats. Although such monitoring may not be feasible in marine systems, the major species of commercial and recreational importance are subject to annual assessments by the Australian Fisheries Management Authority.

This is an area where community groups should have a significant role — in identifying areas of critical importance for migratory species and for gathering and presenting data.

Reporting scale

Local government scale up to IBRA or IMCRA regions.

Outputs

Maps showing areas of habitat used by migratory species, with concentrations of species and abundance of individuals being shown by different symbols. Tables of migratory species showing population trends over time.

Data sources

Historic data are available on the occurrence of all birds, including migratory birds, by units of one degree of latitude and longitude of Australia for one period. These data are based on a survey of birds conducted between 1977 and 1981 (Blakers *et al.* 1984.) This project has not been repeated, however. The data are held by the Royal Australasian Ornithologists Union. A repeat survey should be initiated, which would reflect changes over a 20-year period.

Some marine migratory species which are of economic importance (e.g. Southern Bluefin Tuna) are monitored, and the data are held by the Australian Fisheries Management Authority. Data on some species of marine mammal are held by Environment Australia.

Links to other indicators

The extent and condition of the habitats which support these species will be indicated by 11.1 “Ecosystem diversity” and 11.2 “Number and extent of ecological communities of high conservation potential”.

Indicator 10.11: Demographic characteristics of target taxa

This is an indicator which should be monitored over all jurisdictions.

Description

The demographic characteristics (population size and breeding success) of species selected to illustrate the results of conservation actions.

Rationale

Selected taxa, usually rare or endangered species, provide a focus to direct conservation efforts. Rare or endangered species may be used to gauge conservation success and to raise the profile of conservation actions and are, therefore obvious candidates as target taxa. However, target taxa should also include common species on the basis that species which are common now may not always be so. There is no list of target taxa, and there will not be one target taxon for all jurisdictions; the section “Target taxa” earlier in this report sets out some of the criteria for their selection. There will be a range of different taxa depending on the scale of concern or the region of interest. At the national level, several target taxa should be selected to indicate success or otherwise of a range of conservation actions, or to measure the impacts of particular pressures. For example, the Koala is an obvious candidate because of its high public profile and its use as a conservation “icon” by many community groups. It may be used to monitor the impacts of change in habitat and pressures of urban development. The Orange-bellied Parrot is another obvious candidate because it is endangered, it migrates between Tasmania and the mainland and it depends on habitat subject to a variety of uses and pressures in areas adjacent to considerable human population densities. The Dugong and marine turtles are affected by a range of pressures including fishing and hunting within Australia and in waters of adjacent countries. They may be suitable target taxa, as would be sea birds threatened by fishing methods (e.g. longline fishing). Frogs are another obvious group because of their susceptibility to changes in water quality.

This indicator met ten of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

The baseline will be that produced by the initial population study, with subsequent results compared against that baseline. In some cases, better historical data may be available and these may provide the baseline. For example, the WA Department of Conservation and Land Management uses number of Numbat sightings per 100 km of survey driven as an indicator to monitor present populations of Numbats compared with figures obtained in the mid-1950s as the baseline (Friend 1990).

Monitoring design and strategy

Target taxa will be the subject of detailed ecological studies, followed up with monitoring programs to assess changes in populations and distribution over time. Frequency of monitoring will depend on the degree of endangerment. For example, critically endangered species (e.g. Orange-bellied Parrot) may be monitored annually while less endangered species (e.g. Koala, Salmon Gum) may be monitored at longer intervals. The design of the monitoring strategy will depend on the ecology of the target taxa and the reason for the monitoring.

Reporting scale

In practice, most target taxa will be of restricted distribution and so will be reported at the local government scale. However, some target taxa will be more widespread and therefore amenable to reporting at IBRA and IMCRA region scales, or even continental scales.

Outputs

Tables of population estimates over time and maps of change in distribution and abundance over time.

Data sources

Where studies have already been conducted or are being conducted, data on the ecological parameters required for this indicator are held by State and Territory conservation agencies, Environment Australia, the Australian Fisheries Management Authority, universities, herbaria, museums, CSIRO and, increasingly, community groups and non-government organisations. For newly selected target taxa, it will be necessary to collect data in the field.

Links to other indicators

This indicator is closely linked to the condition indicators of species and ecosystem diversity, the pressure indicator 2.1 "Extent and rate of clearing, or major modification, of natural vegetation or marine habitat", the response indicators 15.1 "The number of recovery plans" and 15.2 "The amount of funding for recovery plans", and Inland Waters Indicators Nos 6.2 "Frogwatch records", 6.3 "Fishkill records" and 6.4 "Waterbirds" (see Fairweather and Napier 1998 for details).

Condition: Condition of ecosystem diversity

INDICATOR 11.1: ECOSYSTEM DIVERSITY

This is an indicator which should be monitored across all jurisdictions.

Description

The number, identity, condition and area of native vegetation types and marine habitat types recognised at the IBRA and IMCRA region scales.

Rationale

Native vegetation type or marine habitat type is a tangible medium for much of biological diversity. Different vegetation types and marine habitat types reflect different ecological and environmental conditions and, therefore, different components of biological diversity. Vegetation and habitat types recognised at the IBRA or IMCRA region level are used here as surrogates for, or descriptors of, ecosystems. More detailed communities can and should be recognised nested within these broad region types for reporting on clearing and habitat fragmentation (see the discussion of "Vegetation types" earlier in this report).

This indicator met 11 of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

The number and identity of vegetation and marine habitat types, and maps and tables showing changes in condition and area of each type. This is a broad-scale indicator used as a surrogate for biodiversity, and there are limitations which should be taken into account in interpretation. Substantial changes in the biological assemblages of these vegetation or habitat types could occur without being detected by monitoring extent and condition alone. Recognising communities within these broad-scale types and monitoring clearing, fragmentation and modification by communities (see Indicator 2.1) constitutes one attempt to overcome these limitations.

Monitoring design and strategy

Using the monitoring design for 2.1 "Extent and rate of clearing, or major modification, of natural vegetation or marine habitat", vegetation and marine habitat types should be listed and mapped for tabulating number, measuring area and assessing condition. Listing, mapping, tabulating and assessing can all be expedited if boundaries are digitised and held in a geographic information system. Remote sensing at the TM scale has the potential to be used for assessing condition, but new research will be required. Some very localised communities, such as mound springs and caves, may not be detected using this monitoring design, but do represent distinct and complementary ecosystems. Such areas are usually known to local or regional land management agencies, and should be added to maps and lists separately.

The baseline should be pre-European settlement extent and condition. New research may be needed to predict this (see Austin and Cawsey 1996; CSIRO 1996a, b, c).

Specht *et al*. (1995) have devised a classification of Australian plant communities and categorised their conservation status. Many of these communities cannot be presented in the form of a vegetation map, so there are problems with regular monitoring and reporting. Nevertheless, the data are amenable to tabular analysis and can be reported in that way. They represent the best existing description, consistent at a continental scale, of Australian ecosystems at the level of detail appropriate for biodiversity reporting. However, the only existing map capable of serving as an interim first approximation of ecosystem diversity at the continental scale is the natural vegetation map in Volume 6 of the Atlas of Australian Resources (Commonwealth of Australia 1990).

Reporting scale

The ecosystems (vegetation and marine habitat types) will have been defined at the IBRA and IMCRA region scales, which are also the appropriate reporting scales. Changes in condition and extent might vary with local government management policies and might also vary according to the susceptibility of different types at the lower community level of classification to threatening processes. It would facilitate monitoring of, and reporting on, these local variations if data were collected at that level and then aggregated, using the nested hierarchical classification (see 2.1 "Extent and rate of clearing, or major modification, of natural vegetation or marine habitat") to the IBRA and IMCRA region scales.

Outputs

Maps and tables showing the change in extent and condition of each vegetation and marine habitat type at the regional scale, broken down, where possible, to communities at the local government level.

Data sources

Environment Australia holds a copy of the Natural Vegetation map from the Atlas of Australian Resources. There is no comparable information for marine habitats, although detailed information exists for a few areas such as the Great Barrier Reef (Great Barrier Reef Marine Park Authority and Australian Institute of Marine Science) and Torres Strait (CSIRO). State environmental authorities can supply information on coastal habitats — such as the distribution of sandy, rocky and muddy shores — but information on the continental shelf and deeper water is lacking (see "Research and development needs" below). CSIRO is collaborating with the States in mapping shallow water habitats. Parts of Western Australia, South Australia, Victoria and Tasmania have been mapped, and it is intended to extend this to the remaining areas. The maps include information on seabed type (e.g. sand, mud or rock) as well as on seagrasses, mangroves and macro-algae.

Links to other indicators

This indicator is linked to 2.1 "Extent and rate of clearing, or major modification, of natural vegetation or marine habitat", 2.2 "Location and configuration of remnant vegetation and marine habitat", 10.1–10.9 "Species diversity, conservation status, economic importance and extent of knowledge", 11.2 "Number and extent of ecological communities of high conservation value", 13.1 "Extent of each vegetation and marine habitat type incorporated within protected areas", Inland Waters Indicator No. 6.7 "Wetland extent" (see Fairweather and Napier 1998 for details), Land Indicator No. 2.4 "Percentage forest, wood, shrub, compared to 1990 base" (see Hamblin 1998 for details), and Estuaries and the Sea Indicator Nos 2.1 "Algal bed area", 2.2 "Beach and dune area", 2.3 "Coral reef area", 2.4 "Dune vegetation", 2.5 "Intertidal reef area", 2.6 "Intertidal sand/mudflat area", 2.7 "Mangrove area", 2.8 "Saltmarsh area", and 2.9 "Seagrass area" (see Ward *et al.* 1998 for details).

Indicator 11.2: Number and extent of ecological communities of high conservation potential

Description

Areas representing extinct, rare, threatened or vulnerable ecological communities or areas of high endemicity needed to represent the range of continental biological diversity fully.

Rationale

This indicator is really for a sub-set of communities and vegetation types, listed under "Ecosystem diversity" and defined at a local scale, that are particularly vulnerable because of their limited extent. Some will be identified as lower level types (communities) nested within the hierarchical classifications used for indicators such as 11.1 "Ecosystem diversity" and 2.1 "Extent and rate of clearing, or major modification, of natural vegetation or marine habitat", which have become localised by clearing or other human activities. Examples include some grasslands, woodlands in areas of intensive agriculture and coastal communities subject to development. Others are naturally localised, and may not be identified even by a fully nested hierarchical classification. Examples include mound springs and caves, including water-filled ones of the Nullarbor Plain or Mt Gambier. Coastal and, particularly, intertidal marine communities are subject to considerable pressures near major cities such as Perth and Sydney. In addition to habitat alterations such as filling or construction, impacts come from pollution and through collection of edible animals and plants. On the continental shelf, the major impacts are from fishing, especially trawling. The monitoring for this has been covered in 2.2 "Location and configuration or fragmentation of remnant vegetation or marine habitat".

This indicator met ten of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

A useful indicator of success or failure of management programs would be the area covered that does not require ongoing intensive management and is therefore self-maintaining.

Monitoring and design strategy

1. Using the monitoring design for Indicator 2.1 "Extent and rate of clearing, or major modification, of natural vegetation or marine habitat", communities and/or vegetation types and marine habitat types that are localised in extent and vulnerable to threatening processes should be listed and mapped.

2. Any naturally localised communities not identified by the hierarchical classification in 1. above which are vulnerable to threatening processes should be added to the list and mapped.

3. The rate of change in extent and condition of these areas should be monitored. Remote sensing has the potential for monitoring some of these areas, but new research will be required. Because many vulnerable communities are already known to local management agencies, information on change in extent and condition may be collected directly from such agencies.

4. The benchmark will be the extent and condition at the time of European settlement.

Reporting scale

Information will be collected at the local scale, but should be reported at the IBRA or IMCRA region scales.

Outputs

Lists of communities and maps and tables showing the changes in extent and condition.

Data sources

There are three potential sources of data:

1. The maps and tables produced for monitoring 2.1 "Extent and rate of clearing, or major modification, of natural vegetation or marine habitat".

2. Local, regional, State-wide and Commonwealth land and marine management agencies.

3. Endangered species legislation has been expanded to include habitats or communities, which may now be listed for formal recognition as endangered — although none have been identified Federally. Such lists are potentially another source of information.

Links to other indicators

This indicator is linked to 2.1 "Extent and rate of clearing, or major modification, of natural vegetation or marine habitat", 2.2 "Location and configuration of remnant vegetation and marine habitat", and 11.1 "Ecosystem diversity".

INDICATORS OF RESPONSES TO PRESSURES AND CONDITION OF BIOLOGICAL DIVERSITY

Response: Regional planning and management, and integrated land and sea management

This subsection presents the indicator used for assessing the extent to which bioregional planning units that emphasise regional environmental characteristics, and are based on environmental parameters, are used in management of natural resources — including the conservation and sustainable use of biological diversity. The issue of management which extends across protected and all other areas (off-reserve conservation of biological diversity) is assessed here.

INDICATOR 12: INTEGRATED BIOREGIONAL PLANNING

Description

The number of management plans, prepared within bioregions, which incorporate management of biological diversity with other management activities, particularly production activities. The amount of funding spent on management planning and management action per km2 of each bioregion.

Rationale

Conservation of biological diversity will only be successful if it is regarded as equal in importance to production-oriented activities in managing all parts of the landscape and seascape. The long-term ecological realities need to be given equal weighting with economic realities in developing integrated management strategies aimed at ecological sustainability. Establishing and maintaining a comprehensive, adequate and representative system of protected areas is essential. However, conservation outside this system of protected areas ("off-reserve") is also essential. Much biological diversity only exists outside this system, and ecological sustainability also depends on the protection and maintenance of these important elements of biological diversity. Therefore, integrated management is required and bioregional planning is the mechanism by which this is identified and programmed.

At the national scale, bioregional planning should be conducted at the level of the IBRA and IMCRA regions. However, to be effective, bioregional planning needs to be based on local integrated planning which is developed at the level at which management takes place. Over most agricultural and pastoral land this will usually be at the sub-catchment scale, involving Landcare groups who are managing the land — although it may also be at the local government level. Mechanisms will need to be developed to establish what contribution the sum of conservation actions at the sub-catchment scale makes to conservation at the bioregional scale.

This indicator met 11 of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

The baseline for interpretation will be the data gathered from the first survey. The concept of bioregional planning for integrated management is a comparatively recent one, which has been applied sparingly to date. Success or otherwise can be gauged by the change in number, and percentage of the area, of bioregions which have effective integrated plans prepared and acted upon, and the change in the amount of funding devoted to planning and management on a bioregional basis.

Monitoring design and strategy

Regional planning is conducted under State and Territory jurisdiction. The progress of bioregional planning should be monitored by surveys of relevant planning authorities to establish how many bioregions (most usefully based on IBRA and IMCRA regions) have integrated management plans which incorporate management of biological diversity as a high priority activity, and the funding involved.

The surveys should examine where planning for biological diversity is incorporated into the planning process, the scale of the planning process, and the funds spent on planning and management.

Reporting scale

IBRA and IMCRA regions.

Outputs

Reporting would be in the form of a table showing the number of bioregions which have integrated plans prepared and acted upon, the percentage of the area of the bioregion covered by such plans and the funding per unit area. This could also be presented in a figure showing the bioregions of Australia with and without effective integrated plans prepared and acted upon.

Data sources

Information on planning is held by State, Territory and Commonwealth planning and conservation authorities. Bioregional planning will take in a range of local government authorities. However, local authorities should be surveyed to find out if they are involved in bioregional planning for integrated management and how much they are spending on it.

Links to other indicators

This indicator is linked to Estuaries and the Sea Indicator Nos 7.2 "Catchment development" and 7.3 "Catchment management programs" (see Ward *et al.* 1998 for details) and Inland Waters Indicator No. 7.2 "Management effort" (see Fairweather and Napier 1998 for details).

Response: Establishment and management of a comprehensive, adequate and representative system of protected areas

This subsection presents indicators to assess the extent to which the terrestrial and marine protected area systems are comprehensive, adequate and representative, and actively managed.

INDICATOR 13.1: EXTENT OF EACH VEGETATION TYPE AND MARINE HABITAT TYPE WITHIN PROTECTED AREAS.

Description

This is an indicator which should be monitored across all jurisdictions. For each vegetation type and marine habitat type, the area included within protected areas as a percentage of the pre-1750 area.

Rationale

Protected areas are necessary, but not sufficient, to sustain biological diversity. The goal of the network of protected areas is to represent, comprehensively and adequately, the full range of biological diversity within lands and waters under Australian jurisdiction. This indicator will measure the degree to which that goal is being achieved.

This indicator met ten of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

This indicator is most easily interpreted by setting percentage targets and monitoring levels of achievement.

To represent a vegetation or marine habitat type comprehensively and adequately, a protected area or set of protected areas should contain samples of the range of variation inherent within the type. This variation is expressed in lower levels of the proposed hierarchical vegetation classifications (see discussion of "Vegetation types" earlier in this report). Any increase or decrease in the extent of representation should include a measure of the increase or decrease in representation of within-type variation.

Analysis and interpretation of this indicator should take account of guidelines developed to set priorities for additions to the National Reserve System, and in particular for assessing gaps in the current reserve system and setting national priorities.

Monitoring design and strategy

1. The maps used for Indicator 11.1 "Ecosystem diversity" should be superimposed on maps of existing protected areas (by IUCN category) within IBRA and IMCRA regions.

2. The extent of representation of each vegetation type and marine habitat type within each region should be determined, and changes in this monitored. The current extent of representation will constitute the baseline. For some terrestrial and marine regions, it may be necessary to use the percentage of the bioregion managed under a conservation plan as a surrogate for proportion of vegetation or habitat type within protected areas.

Reporting scale

Changes should be reported at the national scale within IBRA or IMCRA regions.

Outputs

Maps of the geographical extent of changes in area and tables showing the extent of vegetation or marine habitat type variation.

Data sources

Environment Australia and State and Territory conservation and mapping agencies hold data on protected area by category on geographic information systems.

Links to other indicators

This indicator is linked to indicators of species diversity, 11.1 "Ecosystem diversity" and 11.2 "Number and extent of ecological communities of high conservation value", and Estuaries and the Sea Indicator No. 7.12 "Marine protected areas" (see Ward *et al.* 1998 for details).

Indicators 13.2–13.4: Management of protected areas

Indicator 13.2: The number of protected areas with management plans

Description

The number of protected areas, by class of protection, with management plans for conservation of biological diversity being implemented, compared with the total number of protected areas.

Indicator 13.3: The number of interest groups involved in protected area planning

Description

The number, and lists, of interest groups explicitly involved in the management planning and implementation process, including Aboriginal and Torres Strait Islander peoples.

Indicator 13.4: The resources committed to protected areas

Description

The resources, including funds and personnel, committed to the management of protected areas relative to the resources committed to harvesting biological diversity.

The following discussion refers to Indicators 13.2–13.4.

Rationale

The resources that governments and the community are prepared to spend on managing protected areas give an indication of the commitment to protecting a comprehensive and adequate representation of Australia's biological diversity.

Indicator 13.2 met 11 of the 15 criteria for selection of indicators (Table 2). Indicators 13.3 and 13.4 met five and three of the selection criteria respectively, indicating that these two indicators require considerable research and development to make them operational.

Analysis and interpretation

The level of detail of records kept by different agencies responsible for managing protected areas will no doubt vary, so these indicators may be difficult to analyse and interpret consistently. Nevertheless, these are basic indicators of the response of governments and communities to pressure on biological diversity, and should be monitored. The target for these indicators is that all protected areas have implemented management plans for the conservation of biological diversity which explicitly involve interest groups, and that these plans are supported with the funds and personnel needed to carry them out.

Monitoring design and strategy

The following should be compiled to report on these indicators:

1. Lists of protected areas with implemented management plans, and their location.

2. Lists of protected areas with implemented management plans that explicitly involve local interest groups, and their location.

3. Tables of resources committed by the responsible management agencies to implementing management plans, compared with resources committed to harvesting biological diversity.

Reporting scale

By State and Territory, and at the national scale by IBRA and IMCRA regions.

Outputs

Comparisons of the proportion of protected areas with implemented management plans, funding levels and interest group involvement in the form of tables and statements.

Data sources

Environment Australia, State and Territory conservation and planning agencies, and State, Territory and Federal budgets.

Links to other indicators

These indicators are linked to 11.1 "Ecosystem diversity" and 13.1 "Extent of each vegetation and marine habitat type incorporated within protected areas".

Response: Knowledge of biological diversity, and existing conservation arrangements

Indicator 14: Proportion of bioregions covered by biological surveys

Description

The proportion of each IBRA and IMCRA region covered by surveys to record locations of species and subspecies, and to identify ecosystems, habitats, sites of exceptional diversity and isolated surviving remnants of past distributions, and the frequency of repeat surveys.

Rationale

Australia: State of the Environment 1996 (SoE Advisory Council 1996) pointed out that lack of knowledge of biological diversity was a major impediment to its sustainable management. We lack information on what biodiversity is, how it is distributed and its functional role in the many ecosystem processes on which we depend. Several indicators have been suggested to assess increase in knowledge — e.g. amount of funding for research aimed at understanding biological diversity, number of public employees engaged in its protection, and the amount of legislation and numbers of policies and international agreements aimed at its conservation. These potential indicators are too detailed for national state of the environment reporting, or would be very difficult to gather data for and interpret. However, the area or proportion of each IBRA or IMCRA region covered by biological surveys is a relatively simple indicator of the extent of knowledge of elements of biological diversity.

This indicator met 11 of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

Each reporting period would show the extent of coverage of IBRA and IMCRA regions by biological surveys. Increase in knowledge should be indicated by an increase in the proportion of regions covered by surveys and/or an increase in the level of geographic detail and taxonomic coverage.

Monitoring design and strategy

Monitoring should establish national standards, which would include putting all survey data on geographic information systems. This would allow records per unit area and other statistical data to be compiled. At present, many organisations and individuals carry out research on many aspects of biological diversity throughout the country and its surrounds. However, the maps of coverage and the elements of research interest are scattered in diverse organisations. It should be possible to set up a central register under the Biodiversity Group of Environment Australia. Any requests to carry out biological surveys or ecological research (which have to be approved by State and Territory conservation authorities) could be referred to the central register. As part of the approval process, the proponents could be asked to provide a map of the area involved and the elements of biological diversity to be researched. The issue of "non-destructive" survey work, which may not require a permit, would need to be addressed.

These maps could then be transferred to a central geographic information system for reporting purposes.

Reporting scale

Depending on the geographic information system, this indicator could be reported at the scale of the statistical local area; however, for national reporting, it should be reported at the scale of IBRA and IMCRA regions.

Outputs

Tables of the cumulative percentage of the area of each region covered by surveys or ecological research, and maps showing the location of surveys and research along with the geographic scale and lists of taxa covered. Coverage of mining exploration is already tabulated and mapped, and the same sorts of outputs are appropriate here.

Data sources

Individuals and organisations in Australia engaged in biological survey or other ecological work hold data of this nature. This list includes Commonwealth, State and Territory conservation, environmental and primary industry agencies; universities; CSIRO; non-government organisations; environmental consultants; and mining companies. For example, the Australian Bird and Bat Banding Scheme in Environment Australia has data on the location of all bird and bat banding projects being carried out in areas under Australian jurisdiction.

Response: Management of threatened species and ecological communities

This section presents indicators to assess the adequacy of responses to the endangerment of species and ecological communities.

Indicator 15.1–15.2: Adequacy of recovery planning process

Description

15.1 The number of recovery plans for species and ecological communities threatened with extinction compared with the number of species and communities so classified.

15.2 The amount of funding provided for the implementation of recovery plans compared with the amount specified in the plans for full implementation.

Rationale

A major response to the extinction of a number of conspicuous species has been the enactment of legislation to classify and protect endangered species and, more recently, ecological communities threatened with extinction. The Commonwealth legislation, *The Endangered Species Protection Act 1992,* is an example of this response. The Endangered Species Program was set up under this legislation to prevent further extinctions and restore endangered species and ecological communities to secure status in the wild. Part of this program is the preparation and implementation of recovery plans, with costs of implementation, for endangered species on Commonwealth land and the sea. Some States and Territories also prepare recovery plans under their legislation.

These indicators assess the adequacy of the planning process, while Indicator 10.11 "Demographic characteristics of target taxa" monitors the response of the organisms subject of the recovery plans.

Indicators 15.1 and 15.2 met 11 and eight of the 15 criteria for selection of indicators respectively (Table 2).

Analysis and interpretation

The baseline for Indicator 15.1 would be the number of species or ecological communities for which recovery plans should be prepared. The percentage of species or ecological communities for which plans have been prepared would be the indicator of the planning response.

The total funding specified in the recovery plans would provide the baseline against which to assess the adequacy of the funding response (Indicator 15.2). This would be indicated by the percentage of the base funding actually allocated for implementation of the recovery plans. By preparing a table separating Commonwealth, State and Territories, comparisons may be made between the responses of the different jurisdictions.

Monitoring design and strategy

Lists by Commonwealth, State and Territory of species and ecological communities threatened with extinction, those for which recovery plans have been prepared, funding specified and funding actually allocated should be compiled.

Reporting scale

These indicators should be reported at the national level, categorised by Commonwealth, State and Territory jurisdictions.

Outputs

A table of percentage of species or ecological communities for which recovery plans have been prepared and the percentage of estimated funding actually allocated, shown by jurisdiction.

Data sources

Environment Australia and State and Territory conservation agencies or departments hold information on conservation classification, recovery plans and funding.

Links to other indicators

This indicator is linked to Indicators 10.7 "Conservation status of species", 10.11 "Demographic characteristics of target taxa" and 11.2 "Number and extent of ecological communities of high conservation potential".

Response: *Ex-situ* conservation

Indicators for assessing captive breeding programs, culture collections and germplasm banks are presented here.

INDICATORS 16.1–16.2: *EX-SITU* RESEARCH ON THREATENED SPECIES

Description

16.1 The number of threatened organisms for which there are *ex-situ* research programs compared with the total number of threatened organisms.

16.2 The number of releases to the wild of organisms raised by *ex-situ* breeding programs compared with the number of *ex-situ* breeding programs for threatened organisms.

Rationale

The ultimate objective of management and protection of biological diversity is to maintain all elements in the wild. However, for some elements of biological diversity this is now no longer possible, so *ex-situ* research and development aimed at maintaining populations of threatened species in zoos and botanic gardens, and at breeding and propagation for release back into the wild, is an important component of an overall strategy for maintaining biodiversity. These indicators will measure the extent to which resources are committed to *ex-situ* breeding programs relative to the need, and the relative contribution such programs are making to conservation *in situ*.

Indicators 16.1 and 16.2 both met 11 of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

Interpretation will be based on the change in the number of research programs for breeding captive populations relative to the number of organisms requiring such programs. The first analysis and presentation of the indicator would establish the baseline. An increase in number of programs will mean an increase in response to species endangerment via *ex-situ* breeding programs. Similarly, an increase in the number of releases to the wild from such programs means an increasing response.

Monitoring design and strategy

Research activities and programs designed to maintain threatened species in captivity, and breeding and propagation programs for release back into the wild — including records of successes or failures — should be listed periodically.

The agencies carrying out the research/breeding programs should be responsible for monitoring this, and there should be a mechanism in place for reporting progress to Environment Australia for collation and dissemination.

Reporting scale

Captive breeding programs should be reported by State or Territory and aggregated to the Commonwealth level. Re-introductions and releases to the wild should be reported by IBRA and IMCRA regions so that the proportions of effort and success or failure can be compared between regions.

The appropriate reporting cycle is 3–5 years, in phase with national state of the environment reporting.

Outputs

Table of lists and numbers of threatened organisms by taxonomic group and bioregion for which *ex-situ* programs exist compared with the list and number of all threatened organisms, and the number of releases into the wild by taxonomic group and bioregion.

Data sources

Commonwealth, State and Territory conservation agencies, zoos and botanic gardens, universities, CSIRO and commercial nurseries hold data necessary for developing this indicator.

Links to other indicators

These indicators are linked to indicators of the condition of genetic and species diversity.

Response: Harvesting of native biota

This section sets out indicators for assessing, at a national level, the adequacy of management programs for the sustainable harvesting of native species.

INDICATOR 17.1: THE NUMBER OF MANAGEMENT PLANS FOR ECOLOGICALLY SUSTAINABLE HARVESTING

Description

This is an indicator which should be monitored across all jurisdictions. The number of management plans for ecologically sustainable harvesting compared with the number of organisms being harvested.

Rationale

There are many organisms which are harvested for economic gain as part of an industry (e.g. fisheries, forestry, broom bush), others which are also harvested recreationally (e.g. fish), and some which are harvested by communities as part of their traditional hunting or foraging patterns (e.g. dugong). Harvesting is regarded as one of the pressures on biological diversity and, in the past, has been the cause of rapid decline in some species (e.g. some species of whale). An effective and relatively simple indicator of our response to this pressure is to establish how many organisms are being harvested with management plans to ensure that they are harvested on a sustainable basis, compared with those harvested without such plans.

Indicators based on the amount spent on managing and reporting on harvesting, poaching and trafficking of native biota, or the number of personnel involved in supervising such activities, are probably too difficult to assemble and not sufficiently robust for easy interpretation.

This indicator met 11 of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

The baseline for this indicator would be the first reporting point, with any subsequent change interpreted relative to that baseline. Interpretation should be done by type of harvesting (e.g. forestry, fisheries).

Monitoring design and strategy

Lists should be compiled of organisms which are being harvested, poached and/or trafficked and of organisms which have management plans prepared for their sustainable exploitation and which are actually used for managing the harvesting activities. These lists should be upgraded in phase with national state of the environment reporting.

Reporting scale

This indicator should be reported on at the local government scale and nationally by IBRA and IMCRA regions.

Outputs

Table of numbers of organisms harvested under the management of a plan developed for sustainable exploitation against total numbers of organisms being exploited, expressed by bioregion and sector (forestry, fisheries, etc.).

Data sources

Commonwealth, State and Territory conservation and primary industry agencies hold data on organisms being exploited. For example, in Western Australia the Department of Conservation and Land Management holds records on any biota exploited commercially, with the exception of species exploited by fishers. The data on those are held by the State Department of Fisheries. Both of these agencies have management plans for the exploitation, and for a lessening in pressure.

Links to other indicators

This indicator is linked to the indicators listed under "Pressure: Harvesting" and to Estuaries and the Sea Indicator No. 4.3 "Fish stocks" (see Ward *et al*. 1998).

Indicator 17.2: Effectiveness of bycatch controls

Description

The quantity (by weight or numbers of species) of bycatch compared with the quantity of target organisms (by weight), by harvesting technique.

Rationale

At present, prawn trawlers catch between six and ten times (by biomass) more non-target (or bycatch) species than prawns. Most of the animals caught in this manner are dead when they are discarded. Considerable progress is being made towards modifying trawl gear to reduce the catch of large animals such as turtles. Gear to reduce the incidental catch of fish is also under development. A key measure will be the extent to which this gear is used by the fishing industry and its effectiveness in reducing bycatch. Deaths of dugong caught in gill nets are being addressed by developing a code of conduct for commercial fishers and by banning gill netting in areas of high dugong population density. The number of dugong killed each year in gill nets can be a gauge of the effectiveness of these measures.

The population sizes of six of the world's 14 species of albatross have recently declined. All 11 albatross species that occur in the Southern Ocean have been recorded as being caught on longlines set for tuna. In 1993, at least 3500 albatross were caught on Japanese longlines set in Australian waters. Several measures to reduce this catch are being introduced and others are being tested. They include setting lines at night, using thawed baits and bait throwers to make the baits sink more rapidly, and the deployment of streamers (tori poles) to discourage the birds from taking baits.

This indicator will report on the effectiveness of controls to minimise the non-target species caught during fishing operations.

This indicator met eight of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

The baseline will be the first set of data analysed for this indicator and any change related to that. For example, a reduction in the weight of bycatch compared with target organisms will point to greater efficiency of catch and a lessening of pressure on non-target organisms.

Monitoring design and strategy

Methods to evaluate the effectiveness of bycatch reduction gear are presently under development. Trawlers in Commonwealth fisheries are required to record their use of bycatch reduction devices as well as incidental capture of turtles. State Fisheries agencies should be encouraged to adopt similar reporting measures. The reporting indicator could be the proportion of trawlers using bycatch reduction gear for large animals like turtles and rays, as well as for fish, and the total amount of unwanted bycatch discarded from prawn and fish trawlers, scaled for fishing effort.

Dugong kills in Queensland are monitored by the Queensland Boating and Fisheries Patrol, but the long shoreline and remote nature of much of the coast make accurate assessment difficult. Gaining the cooperation of fishers is essential. The reporting indicator could be the total number of dugong killed per year by gill nets, which would be even more useful if it could be scaled for fishing effort.

The effectiveness of measures to reduce the incidental catch of albatross and other seabirds is monitored by Australian observers on longline fishing vessels. The reporting indicators should be the numbers of seabirds killed each year by longlines, which would be even more useful if it could be scaled for fishing effort.

Reporting scale

Reporting should be nationally by method of fishing.

Outputs

Figures of changes in indicators over time or tables of data expressed by type of fishery.

Data sources

Commonwealth, State and Territory fisheries agencies should hold the data necessary to develop these indicators.

Links to other indicators

This indicator is linked to the pressure indicators 8.4 "Ratios of bycatch to target species in trawl fisheries and amount of material discarded at sea: and Estuaries and the Sea Indicator No. 4.5 "Trawl fishing area" (see Ward *et al.* 1998 for details).

Response: Retention and management of native biota

This section presents indicators to assess the current rate of change in, distribution of, and control of, clearing of native vegetation on a national basis and the development of national inventories of native vegetation. Indicators to assess management of remnant vegetation are also presented.

Indicators 18.1–18.3: Controls on clearing of native vegetation

These are indicators which should be monitored across all jurisdictions.

Indicator 18.1: Area of clearing officially permitted.

Description

The area of native vegetation subject to permits to clear, by area of remaining vegetation and by reason for clearing.

Rationale

Clearing of native vegetation is still one of the major pressures on biological diversity (SoE Advisory Council 1996), and the extent of this pressure is indicated by 2.1 "Extent and rate of clearing, or major modification, of natural vegetation or marine habitat". One major indicator of response is to establish how much vegetation, by type, is still being cleared under officially approved clearing permits. One suggested indicator for controls on clearing is the extent of legislative or other controls on the clearing of native vegetation. However, it matters little how much legislation has been passed if the legislation is not enforced. Hence it is more appropriate to use an indicator that provides information on the actual amount subject to clearing applications and examine this in the light of the conservation status of the particular vegetation types.

This indicator met 11 of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

The baseline for this indicator should be the percentage of pre-European settlement vegetation remaining, by type. The total amount of each vegetation type subject to clearing permits may then be compared with the extent of remaining vegetation. It is important that this indicator is monitored at the local government as well as State and Territory scales, because at the local scale it is feasible to make meaningful comparisons between the extent of the clearing proposed under permits and the amount of that vegetation type still extant.

Monitoring design and strategy

Ideally, this indicator needs a vegetation classification scheme as proposed in the discussion under "Vegetation types" earlier in this report and in "Research and development needs" later. This would allow data collected at the local scale to be aggregated to the national scale. Applications for permission to clear should specify the vegetation type involved in the permit. It would then be relatively simple to collect data on the amount of each vegetation type being subject to requests to clear, the reasons for clearing, how much is covered by permits to clear, how much is actually cleared, and how this compares with the amount of that vegetation extant.

Reporting scale

This indicator should be reported by IBRA regions at the national level.

Outputs

This indicator may be reported using tables (by State and Territory) of area of particular vegetation types subject to clearing applications, the reasons for clearing, the area for which clearing permits are granted, and the area still extant. This information could also be presented graphically.

Data sources

Data on clearing permits are held by State and Territory agencies of environmental protection, primary industries and conservation. However, the data usually do not specify which vegetation types are covered by clearing permits, and data on how much was actually cleared under the permits are not available. In addition, permits to clear relatively small amounts may not be issued by the same authority which issues permits to clear larger amounts.

Links to other indicators

This indicator and 2.1 "Extent and rate of clearing, or major modification, of natural vegetation or marine habitat" comprise the major assessments of the pressures on biological diversity and the response to those pressures. Accordingly, they are critical indicators which should be developed as a matter of high priority. This indicator is also linked to Land Indicator No. 2.2 "Percent of each IBRA region lost to development relative to percent already affected by native vegetation loss" (see Hamblin 1998 for details).

Indicator 18.2: Area cleared to area revegetated

Description

The area of native vegetation cleared by vegetation type compared with the area revegetated.

Rationale

At present, the rate of loss of native vegetation in Australia exceeds the rate of revegetation. Because of the importance of native vegetation for conservation of biological diversity, an indicator which measures the rate of loss of vegetation compared with the rate of replacement is important.

This indicator met seven of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

Data collected for 18.1 "Area of clearing officially permitted" could be used, together with data on type and extent of revegetation. The baseline would have to be the first measurement of the indicator, and subsequent interpretation would assess change relative to that baseline. A significant increase in the amount of native vegetation being planted for conservation purposes would indicate a positive response for biological diversity.

Revegetation would need to be carefully defined. There are no data at present that show that plantations have major benefits for conservation of biological diversity, so plantations and revegetation using exotic species for farm forestry would not be included in this indicator. Revegetation would need to include ground cover and shrub layers, as well as canopy layers (structural diversity).

Monitoring design and strategy

Remote sensing cannot establish the purpose, extent, structural complexity, or dominant species of revegetated areas. Data on the purpose and extent of revegetation would have to be obtained by surveys of the type conducted by the Australian Bureau of Statistics of the agricultural and mining industries. At present, the ABS does report on revegetation (see Australian Bureau of Statistics 1996, Figs 12.2.1.17 and 12.2.1.18). Surveys by the ABS would need to be specifically targeted towards this indicator.

Reporting scale

This indicator should be reported by IBRA regions at the national level.

Outputs

This indicator may be reported by tables showing the extent of native vegetation being cleared, together with the extent of revegetation by purpose (e.g. wind erosion, water table control, farm forestry, nature conservation, etc.) and dominant species.

Data sources

The Australian Bureau of Statistics, State and Territory agencies of conservation and primary industries and Greening Australia hold some data on revegetation. However, there are few data on species planted by area (except for commercial species) or on the success of revegetation. This indicator will require data that are more specific than those currently held.

Links to other indicators

This indicator is closely linked to 18.1 "Area of clearing officially permitted".

Indicator 18.3: Number of lending institutions considering biological diversity

Description

The number of lending institutions which take biological diversity into consideration, including the impacts of clearing, in their policies compared with the total number of lending institutions.

Rationale

A considerable amount of ecological damage has resulted from short-term economic incentives. Lending institutions are in a position to influence decisions on land management, including clearing, by having conditions included in their lending policies which take biological diversity and the need to restrict clearing into account. An indicator for this would be extremely useful in interpreting changes in the attitude of banks and other lending institutions towards conservation of biological diversity.

This indicator met ten of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

The baseline for this indicator would be provided by the first measurement, and any changes interpreted relative to that. An increase in the number of institutions taking the need to conserve biological diversity into consideration in formulating lending policies would indicate an increase in awareness of its importance.

Monitoring and strategy

The data for this indicator could be obtained by periodic surveys of all lending institutions. The surveys could take the form of mail-out questionnaires, and survey cycles should be in phase with national state of the environment reporting cycles.

Reporting scale

Compilations at both national and State and Territory levels would be appropriate for this indicator.

Outputs

Tables illustrating changes in number of institutions over time.

Data sources

Data would need to be obtained from the lending institutions themselves.

Response: Control of alien species and genetically modified organisms

Indicators for assessing progress towards control of alien species and genetically modified organisms are presented in this section.

Indicators 19.1–19.3: Control of exotic/alien/genetically modified organisms

Description

19.1 The number of management plans for exotic (or alien) and genetically modified organisms outside captivity or cultivation, compared with the number naturalised.

19.2 The number of research programs into impact on, and control of, exotic (or alien) and genetically modified organisms, compared with the number of organisms naturalised.

19.3 The amount spent on research into and control of exotic (or alien) and genetically modified organisms, compared with the estimated amount required.

Rationale

Exotic or alien organisms outside cultivation or captivity are a major pressure on biological diversity. Genetically modified organisms have the potential to become pressures in the same way exotic or alien organisms are now. The three indicators proposed should provide information on the adequacy or otherwise of the response to the pressures posed by these organisms on biological diversity.

Indicators 19.1 and 19.2 met ten of the 15 criteria for selection of indicators while Indicator 19.3 met only five (Table 2).

Analysis and interpretation

These indicators require comparisons of two values, and the interpretations are based on judgement of the adequacy of the number of management programs, research programs and funding provided in relation to the size of the problem. The baselines would be the values established at the first survey. The adequacy or otherwise of the current response would be clear from the first set of figures. The closer the values, the better the response.

Monitoring design and strategy

These indicators would be based on a survey of agencies involved in the management of, and research into, exotic organisms. The number of such organisms outside cultivation and captivity is reasonably well known for vertebrates, higher plants and some invertebrates, but knowledge is poor for most other organisms except the more obvious problem organisms such as *Phytophthora cinnamomi* in south-western Australia. The survey would be used to establish the number of management and research programs.

Recovery plans for endangered species prepared under Commonwealth and some State and Territory legislation specify the funding required to implement the plans. These figures are not required for control programs for exotic organisms. However, it would be possible to establish the amount spent on research and control by survey of the agencies carrying out the work. Estimates of the amount required would be much more difficult, and the error involved in this type of estimate may render it impractical.

Reporting scale

The national scale is appropriate for reporting on these indicators; however, they could be reported on a State and Territory basis to assess the responses of these jurisdictions.

Outputs

Tables showing comparisons between what is currently allocated against what is required.

Data sources

Data on the programs and funding should be held by Commonwealth, State and Territory agencies involved in management concerning, and control of, exotic organisms.

Links to other indicators

These indicators are linked to 3.1 "Rate of extension of exotic species into each IBRA" (Land Indicator No. 4.1) (see Hamblin 1998 for details) and Indicator 3.2 "Pest numbers" (Estuaries and the Sea Indicator No. 3.11) (see Ward *et al.* 1998 for details).

Response: Control of the impacts of pollution on biological diversity

Indicator 20: Control over the impacts of pollution on biological diversity

Description

Amount of funding for, and number of, research programs into the effects of pollution on biological diversity and how to alleviate them, and number of federal, State and local laws or regulations that explicitly deal with the impacts of pollution on biological diversity.

Rationale

Pollution affects biological diversity in ways which are not yet fully understood although, depending on the kind of pollution, biological diversity in the sense of the number of species may decrease or increase locally. The lack of basic knowledge about the impacts of pollution means that research is needed; the level of funding and intensity of research effort, manifest in the number of research programs, are appropriate response indicators. The amount of legislation and regulation concerned with the impacts of pollution on biological diversity is a measure of authorities' responses to pressures posed by pollution.

This indicator met eight of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

Analysis would be by comparing the number of research programs directed explicitly at understanding the effects of pollution on biological diversity, and their level of funding, with the baseline, which would be the first value of this indicator. Interpretation of this indicator will be enhanced if research programs are classified according to type of pollution (Fairweather and Napier 1998, Hamblin 1998). The importance of this indicator will decline as the understanding of pollution effects increases, so interpretation should include a scientific assessment of progress. Once understanding of the effects of different types of pollution is agreed to be adequate, and as methods for ameliorating those effects are developed, this indicator should change to one which monitors the implementation of new knowledge in management programs and policy.

Monitoring design and strategies

This indicator would depend on surveys of research organisations and governments, with the timing of the surveys in phase with the national state of the environment reporting cycle. Data collected would be lists of research activities, the amount spent on the effects of pollution on biological diversity, and lists of legislation and regulations.

Reporting scale

Data collected by States and Territories, reported at that level, and aggregated for reporting at the national scale.

Outputs

Outputs should be lists of: research activities, their results and levels of funding; and legislation and regulations.

Data sources

Data sources are State and Territory pollution control agencies, universities, CSIRO and other research organisations undertaking research on the effects of pollution on biological diversity, and legislative and regulative bodies.

Response: Reduction of impacts of altered fire regimes on biological diversity

INDICATOR 21: REDUCING THE IMPACTS OF ALTERED FIRE REGIMES

Description

The number of management plans which take account of the impacts of fire on biological diversity, by vegetation type.

Rationale

Altered fire regimes may change biological diversity. Agencies responsible for fire management, such as State and Territory forest and conservation agencies and fire control boards, should be implementing plans which take current knowledge into account. In the meantime, research should continue into the differential effects on components of biological diversity according to the variables of fire regime, intensity and seasonality, and the practices adopted by management agencies.

This indicator met six of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

Lists (and numbers) of fire management plans explicitly dealing with biological diversity and changes in those lists (and numbers) over time can be used to monitor the extent to which fire management planning takes account of biological diversity.

Monitoring design and strategy

Agencies responsible for management of, and research into, fire should be monitored by surveys which address the following points.

1. The number of fire management plans which explicitly take into account the effects of fire on biological diversity compared with the total number of fire management plans prepared.

2. The number of research projects into the impacts of different fire regimes, intensity and seasonality on biological diversity and the level of funding for those projects.

3. Over a reporting cycle in phase with the national state of the environment reporting cycle, the number of management plans updated with the results of research into the effects of fire on biological diversity.

Reporting scale

The reporting scale should be States and Territories, with aggregation to the national scale.

Outputs

Lists of management plans explicitly dealing with the effects of fire on biological diversity and lists of research activities and levels of funding for research activities examining the effects of fire on biological diversity.

Data sources

Data sources are State and Territory agencies of conservation and those responsible for the management of fire, universities and CSIRO.

Links to other indicators

This indicator is linked to Indicator 6 "Areal extent of altered fire regimes".

Response: Minimising the potential impacts of human-induced climate change on biological diversity

INDICATOR 22: MINIMISING THE POTENTIAL IMPACTS OF HUMAN-INDUCED CLIMATE CHANGE ON BIOLOGICAL DIVERSITY

Description

The level of research into the effects on biological diversity of different climate change scenarios.

Rationale

The broad-scale distribution patterns of species and ecosystems are controlled, to a large extent, by climate. Climate change may render some areas unsuitable for the species and ecosystems which currently occupy them, while making new areas suitable. The directions which climate change might take are still poorly understood, and the impacts on biological diversity are even more poorly understood. At this stage, the most appropriate response is research into the possible effects under different climate change scenarios.

This indicator met eight of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

The number of research programs directed explicitly at understanding the responses of organisms to climate change, and the level of funding for these programs will indicate the extent to which efforts are being made to predict the impact of climate change on biological diversity. The value of this indicator will decline as the understanding of responses increases, so interpretation should include a scientific evaluation of progress. Once understanding is agreed to be adequate, this indicator should change to one which monitors the implementation of relevant knowledge in management programs and policies.

Monitoring design and strategy

This indicator requires surveys of research organisations in phase with the national state of the environment reporting cycle. Data collected would be lists of research activities and the amount spent on them. Monitoring should also include a scientific evaluation of the results of the research projects.

Reporting scale

The data should be reported at the State and Territory level and aggregated for reporting at the national scale.

Outputs

Outputs should be lists of research activities, levels of funding and an evaluation of progress.

Data sources

Data sources are State and Territory conservation agencies with climate change research programs, universities and CSIRO.

Links to other indicators

Indicators of climate change have been developed for the atmosphere theme.

Response: Planning to minimise the impacts of development on biological diversity

Indicators 23.1–23.2: Planning to minimise the impacts of development on biological diversity

Description

23.1 The number of local governments with management plans for conservation and maintenance of biological diversity compared with the total number of local governments.

23.2 The number of companies with management plans for conservation and maintenance of biological diversity compared with the total number of companies.

Rationale

Ecologically sustainable development requires that the impacts of our activities on biological diversity be minimised. Integrated bioregional planning is one of the planning mechanisms being instituted to minimise impacts on the environment. Local government is directly responsible for land use and planning over much of the country and much development is carried out by companies; indicators are needed to reflect this.

In the agricultural and pastoral areas, Landcare groups have the potential to play a major role in minimising the impacts of development and other land use activities. Indicators of the role of Landcare are contained in Hamblin (1998).

These indicators met eight and seven of the 15 criteria for selection of indicators respectively (Table 2).

Analysis and interpretation

The baseline for these indicators should be zero, in that no concern for environmental issues would mean that no management plans would incorporate environmental concerns. Realistically, the baseline would be established by the first set of indicators developed and future trends interpreted against that set. Any increase in the percentage of local governments or companies taking biological diversity into account in their planning processes would indicate more acceptance of the need to minimise environmental impacts on biological diversity.

Monitoring and strategy

These data could only be gathered by survey. The Australian Bureau of Statistics has a well-established protocol for collecting data such as these. Surveys could be conducted on a 3–5 year basis, in phase with the national state of the environment reporting cycle.

Reporting scale

These indicators should be reported at the national scale. However, if possible they could be reported by IBRA regions to show where environmental concerns were highest and lowest.

Outputs

Output should be in the form of tables listing numbers of local governments or companies with management plans and the total numbers of local governments and companies (by industry). The indicators could also be mapped by IBRA regions.

Data sources

These data would need to be obtained directly from local government and companies.

Links to other indicators

These indicators are linked to Indicators 12 "Integrated bioregional planning", 25.1 "Local government management of biological diversity" and Land Resources Indicator No. 1.9 "Percentage of land managers using best practice by tenure" (see Hamblin 1998).

Response: Improving our knowledge of biological diversity

Indicators 24.1–24.8: Improving our knowledge of biological diversity

Description

24.1 The number of species, by taxon (as for indicator of species diversity), described over a set reporting cycle.

24.2 The number of working taxonomists per taxon, and the estimated number of undescribed species per taxonomist.

24.3 Funding for taxonomy.

24.4 Number of research programs and levels of funding for research aimed at identifying the most appropriate proxies or surrogates for biological diversity.

24.5 Number of research programs and the levels of funding for research aimed at illuminating the role of biological diversity in ecological processes.

24.6 Number and location of long-term ecological monitoring sites by vegetation type within IBRA and IMCRA regions.

24.7 Percentage of Federal, State and Territory, and local government budgets spent on conservation of biological diversity.

24.8 Number of, and levels of funding for, research programs aimed at recording and ensuring the continuity of ethnobiological knowledge, with the approval and involvement of the indigenous peoples concerned.

Rationale

Our poor knowledge of biological diversity must be improved if effective management to sustain both biological diversity and production is to be implemented. We need to improve, develop or foster:

- the description of biological diversity;
- understanding of the ecological processes involving, or functions of, different components of biological diversity;
- a predictive understanding of the factors leading to declines and resurgences of populations of species; and
- the ethnobiological understanding of indigenous peoples.

A complete description of biological diversity and an understanding of all the processes involved in ecosystems are a long way off, yet policy-making, planning, management and reporting must still proceed. Therefore, an urgent need is for knowledge of the most appropriate proxies or surrogates for biological diversity — the partial measures that can be used, in the absence of complete knowledge, to monitor changes in biological diversity.

These indicators met 11, eight, six, six, six, six, nine and eight of the criteria for selection of indicators respectively (Table 2).

Analysis and interpretation

Increases in the number of species described (24.1), the number of taxonomists per taxon and the estimated number of undescribed species per taxonomist (24.2), and the levels of funding for taxonomy (24.3) will identify gaps in taxonomic coverage in order to direct resources to fill this gap. The figure for number of taxonomists per taxon will only be useful if it is collected for the reporting period and includes some estimate of time spent on systematics. Some figures have been presented; for example, Greenslade and New (1991) present a table based on material from B.R. Richardson which shows 190 taxonomists interested in tetrapods (of which there are about 3600 species) and 141 interested in insects (of which there are 125 000 species). They point out that the numbers include all biologists expressing interest in systematics, yet probably only a third work full time in this field. The data on estimated number of undescribed species per taxonomist demonstrate the vastly different research efforts devoted to different taxonomic groups. For example, Richardson's material (Greenslade and New 1991) indicates ranges of from three undescribed species per taxonomist for tetrapods to 1260 for helminths.

Because biological diversity is such a broad concept there will probably never be agreement on the "best" proxy, or set of proxies, but as knowledge increases there should be progressive iteration towards this goal, and reporting mechanisms (24.4) should be adaptable to change accordingly. Interpretation of 24.5 and 24.6 is based on lists of activities, by vegetation type, within IBRA and IMCRA regions. Changes in the percentage of funding allocated to management and conservation of biological diversity (24.7) by the various levels of government will indicate the responses of those governments.

At present there is no indication of the extent of indigenous ethnobiological information, so the baseline for 24.8 would be the results of the first survey to establish the extent of the collation of such information.

Monitoring design and strategy

Data for this set of indicators should be collected every 3–5 years, depending on the national state of the environment reporting cycle.

24.1 The number of species by taxon (as for indicator of species diversity) described over that reporting cycle would be taken from data available from museums, herbaria, etc.

24.2 The data on the number of taxonomists involved per taxon would be taken from surveys of museums, herbaria, etc.

24.3 Data on the amount of funding for taxonomy should be collected from surveys of the same sources of data as for 24.1 and 24.2.

24.4 Research activities aimed at identifying the most appropriate proxies or surrogates for biological diversity should be identified and the amount of funding for such research established.

24.5 Research activities directed explicitly at illuminating the role of biological diversity in ecological processes should be identified and the amount of funding for such research established.

24.6 The number and location of long-term ecological monitoring sites by vegetation type within IBRA and IMCRA regions should be established.

24.7 The percentage of Commonwealth, State and Territory, and local government budgets spent directly on conservation of biological diversity should be established.

24.8: Data on the extent of indigenous ethnobiological information could only be obtained by appropriate surveys of indigenous communities.

Reporting scale

All of these indicators, except for 24.7, should be reported at the State and Territory scale in the first instance and aggregated for national reporting. Indicator 24.7 should include local government data in addition to those from the other two tiers of government.

Outputs

Outputs should be a database from which lists of new species can be compiled, and tabulations of taxonomists by taxon, research activities and levels of funding, and number of indigenous communities collating ethnobiological information.

Data sources

Repositories of biological collections such as museums and herbaria, and agencies such as the Australian Biological Resources Study which fund taxonomic research, will hold the data necessary for development of Indicators 24.1–24.3. Gathering data for Indicator 24.4 is more difficult. Universities, CSIRO and research arms of State and Territory natural resource management agencies would have to be asked specifically for this information. However, the identification of suitable proxies or surrogates is so fundamental to reporting on the state of biodiversity that it should be monitored as a response indicator. Universities, CSIRO and the research arms of State and Territory natural resource management agencies should hold the data needed for Indicators 24.5 and 24.6. Data for Indicator 24.7 would be obtained from budget documents of the various levels of government, and data for Indicator 24.8 would be obtained from indigenous communities.

Response: Involving the community in conservation and management of biological diversity

Indicators 25.1–25.2: Involving the community in conservation

Indicator 25.1: Local government management of biological diversity

Description

The number of local governments which employ an officer responsible for planning and developing programs for the conservation and maintenance of biological diversity, compared with the number of local governments in Australia.

Rationale

"The community" is not a discrete entity which can be surveyed readily to find out what involvement there is in issues like environmental protection. Local government has the capacity to influence much of what happens in relation to the conservation and maintenance of biological diversity because many of the decisions on land use are made at this level. Therefore it is important to have an indicator of how local government is involved in the conservation and maintenance of biological diversity. The simplest way of indicating this is to find out how many local government authorities employ staff specifically to address issues such as the conservation and maintenance of biological diversity.

This indicator met seven of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

The baseline for this indicator would be zero as a complete lack of staff responsible for issues connected with biological diversity is the worst situation. An increasing percentage of local governments with such officers would indicate greater involvement in these issues.

Monitoring and strategy

The data for this indicator would need to be collected by surveys. The protocols for conducting such surveys have been well developed by the Australian Bureau of Statistics. It is feasible to survey all local government authorities. The data would only need to be collected every 3–5 years, and ideally should be in phase with national state of the environment reporting cycles.

Reporting scales

This indicator would be reported at the national scale; however, it could be compared with IBRA and IMCRA regions to assess regional differences in involvement.

Outputs

The output would be a table showing the percentage of local authorities employing staff involved in conservation and maintenance of biological diversity and a map showing the distribution of such local authorities overlaid on IBRA and IMCRA regions.

Data sources

The Australian Bureau of Statistics would be the source of these data, via local authorities.

Indicator 25.2: Involvement of community groups in conservation of biological diversity.

Description

The number and size of community groups involved in conservation and maintenance of biological diversity.

Rationale

While it would be extremely expensive to establish how many individuals are involved in conservation of biological diversity, an indication of community involvement can be obtained in a cost-effective way by looking at the aims and number of members of community groups involved in environmental issues.

This indicator met seven of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

An increase over time in membership of community groups directly involved in issues connected with biological diversity and an increase in the number of such groups would be indicative of increasing community involvement in the conservation and maintenance of biological diversity.

Monitoring design and strategy

The data for this indicator would be obtained by surveys of community groups to establish the aims of the groups and their membership. National organisations such as the World Wide Fund for Nature Australia, the Australian Conservation Foundation, Greening Australia and the Wilderness Society are obvious candidates for monitoring. Smaller, more focused, local issue-based groups (e.g. Friends of the Forests, Malleefowl Preservation Society) should also be monitored, as many people are involved in local conservation issues but not in national issues. Surveys of the groups could be conducted every 3–5 years, in phase with national state of the environment reporting.

Reporting scale

This indicator would be reported nationally.

Outputs

The output should be tables showing number of community groups involved in conservation and membership of such groups.

Data sources

The data for this indicator would need to come from the groups themselves.

Links to other indicators

Indicators relevant to community involvement in conservation of biological diversity are also presented in other reports on Environmental Indicators for National State of the Environment Reporting: Estuaries and the Sea Indicator No. 7.4 “Coastal care community groups” (see Ward *et al*. 1998 for details) and Inland Waters Indicator No. 7.3 “Participation” (see Fairweather and Napier 1998 for details).

Response: Australia's international role in the conservation of biological diversity

INDICATOR 26: AUSTRALIA'S INTERNATIONAL ROLE IN THE CONSERVATION OF BIOLOGICAL DIVERSITY

Description

The number of international agreements signed by Australia, including trade and aid agreements, which specifically address biological diversity, and the number implemented.

Rationale

The activities and interests of Australia extend beyond its borders, and these interests and activities should accord with Australian best practice in the conservation and maintenance of biological diversity. In addition, some components of Australia's biological diversity, such as migratory species, include other countries in their range.

This indicator met seven of the 15 criteria for selection of indicators (Table 2).

Analysis and interpretation

Comparisons between reporting cycles will facilitate an assessment of the contribution Australia is making to international initiatives for the sustainable use of biological diversity — including changes in the awareness of the significance of biological diversity, and in the implementation of practices designed to sustain biological diversity on an international scale.

Monitoring design and strategy

1. The international treaties with a biological diversity component signed by Australia should be listed and compared with the number implemented, and changes monitored.

2. The Australian aid and trade agreements which include the sustainable use of biological diversity should be listed, and changes in that list monitored. The Australian aid and trade organisations which have officers whose duties explicitly include the sustainable use of biological diversity should also be listed, and changes monitored. This list should be compared with the number of officers who have proven expertise and/or training in conservation and the ecologically sustainable use of biological diversity.

3. The list of Australian companies which develop natural resources operating outside Australia should be compared with the list of companies which explicitly include conservation and the maintenance of biological diversity in their charter. Lists of breaches of best practice in relation to conservation and maintenance of biological diversity should be maintained.

4. The international agreements on the conservation of migratory species habitats should be listed, and their effectiveness assessed by monitoring their implementation both in Australia and in other signatory countries.

Reporting scale

The national level is the appropriate reporting scale.

Outputs

Outputs should be comparative tables listing:

1. international agreements and the number implemented;

2. aid and trade organisations and those with a commitment to sustaining biological diversity;

3. trans-national Australian companies, and those with a commitment to sustaining biological diversity; and

4. migratory species agreements, and those that are effective in conservation of migratory species.

Data sources

Records of relevant government departments and non-government aid organisations should provide the data for international treaties and international aid and trade agreements. The Minerals Council of Australia maintains a register of Australian companies which have signed the Australian Minerals Industry Code of Environmental Management. This register, together with company registers (e.g. the stock exchange) and annual reports, should provide much of the data relating to companies with a commitment to sustaining biological diversity. However, data on breaches of best practice outside Australia may be harder to obtain. Records of relevant government departments both in Australia and in other signatory countries, and the number of management plans for these habitats both in Australia and in other signatory countries, would provide the data on migratory species agreements.

Research and development needs

As pointed out in the introduction, most of the indicators of biological diversity proposed in this report have research and development requirements associated with them. For example, there are severe taxonomic difficulties facing biologists attempting to characterise ecosystems and to detect change. For many terrestrial and marine systems, the fraction of species known and described is small and protocols for recognising species are poorly developed. Several of the proposed indicators depend on consistent species recognition by scientists from several agencies, and this is not possible at present for many marine and terrestrial invertebrates and microorganisms.

Some specific research and development issues are described below. Given that most of the proposed indicators have research and development requirements, priority for research and development should be established by deciding on the priority for making particular indicators operational.

Human demand on natural resources

An indicator will need to be developed which clearly shows where pressures relating to human demand for natural resources for Australian consumption and export are greatest. The concept of the "ecological footprint" has been proposed to meet this need, but considerable research and development will be required to make it operational.

Surrogate indicators and biological diversity

It will always be impossible to measure all biological diversity, so the development of adequate predictive surrogates is necessary. Surrogate indicators would:

- help ameliorate the severe resource constraints that currently restrict, and will continue to restrict, efforts to monitor biological diversity; and

- help synthesise a wide range of information on changes to the environment that underpin movements in indicators of biological diversity. Surrogate indicators may prove to be valuable for monitoring species diversity — including the distribution and abundance of biota — as well as species richness and ecosystem diversity.

Potential surrogates of elements of biological diversity include:

- habitat complexity and condition;

- ecological processes such as nutrient cycling, soil stability and water retention;

- abiotic processes such as bioclimatic envelopes; and

- subsets of taxa which represent biological diversity within a region in some way.

For example, it is often assumed that a relationship exists between natural vegetation cover and the list and number of species and their relative abundance. Little or no research has specifically focused on the usefulness of surrogates such as vegetative cover or their relative efficiency, and this is an important and promising area of research.

Genetic diversity

The main areas for further research to support implementation of genetic indicators for state of the environment reporting relate to:

- Elucidating links between different indicator groups. For example: what is the relationship between population size and genetic variation for arthropods? This "ground-truthing" of genetic inference, based on the use of surrogate indicators such as population size, is crucial as these types of surrogates are indicators that are likely to be monitored widely.

- Understanding how different groups of organisms are historically structured (e.g. whether they are connected or fragmented, or whether they were genetically depauperate) and how various pressures on their habitats affect the extent to which their populations are separated. A determination of whether genetic erosion has any consequences for the phenotypic fitness of organisms also requires investigation.

- Meaningful interpretation of data derived from monitoring of the state of Australia's genetic environment is practically impossible unless there are baseline data on genetic diversity for groups of species. Such information is currently missing for many groups such as arthropods, fungi, bacteria, most marine animals and invertebrates. This requires a substantial research effort.

Ecosystem diversity

A number of biological diversity indicators of pressure, condition and response require maps of ecosystems, or ecosystem surrogates such as vegetation types and marine habitat types (see discussion under "Vegetation types" earlier in this report). Because it would be most satisfactory to be able to monitor and report on these indicators at local as well as regional and national scales, these maps should be structured hierarchically. That is, aggregating local classifications up to regional and national scales should derive higher-level classifications. Proven multi-variate clustering methods exist for this purpose, although there are limitations on the resolution of available data. The attributes might be structural at higher levels and floristic at lower levels. For research purposes, it would be most practical to concentrate on areas where there are most data (e.g. forests) or where conservation problems are most severe (e.g.., woodlands in the wheat–sheep zone).

The research problem is to produce a new map of ecosystems of Australia (or two maps, marine and terrestrial) derived from multivariate classifications of vegetation floristics, structure and/or environmental variables. The decision on which variables to use at which level is a major component of the research project.

Ecosystem health

State of the environment reporting seeks to answer questions such the following:

- Are ecosystems changing, and if so, to what extent?
- Are degraded ecosystems likely to continue to degrade?
- To what extent does degradation precede major collapse of an ecosystem?
- Is our management of the environment ecologically sustainable?

Indicators of ecosystem health would facilitate reporting on ecosystems (see Environment Protection Authority 1997). However, this area of research is only recent. In particular, there appears to be little agreement in the literature and among those working on concepts of ecosystem health on which functions, characteristics or ecosystem processes should be selected for indicator development, and how these are related to overall assessments of the health of particular ecosystems.

A useful starting point would be a joint workshop on ecosystem health, with the participation of people involved in developing indicators for inland waters, land resources, estuaries and the sea, and biological diversity at the national, State and Territory, local government and sector levels.

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References

Angermeier P. L. and J.R. Karr, (1994) Biological Integrity versus Biological Diversity as Policy Directives. *BioScience* **44:** 690–-697.

Austin M. P. and E.M. Cawsey (1996) A Preliminary Forest Community Classification for Southeastern New South Wales. Report for NSW National Parks and Wildlife Service. CSIRO Division of Wildlife and Ecology, Canberra.

Australian Bureau of Statistics (1996) Australians and the Environment. Australian Government Publishing Service, Canberra, ACT.

Bakkes J. A., G.J. van den Born, J.C. Helder, R.J. Swart, C.W. Hope, and J.D.E. Parker (1994) An Overview of Environmental Indicators: State of the Art and Perspectives. UNEP/EATR.94–-01, RIVM/402001001. Environmental Assessment Sub-Programme, UNEP, Nairobi.

Beattie, A. J. (ed) (1995) Biodiversity: Australia's Living Wealth. Reed Books, Chatswood, NSW.

Blakers M., S.J. Davies, J. F. and P.N. Reilly (1984) The Atlas of Australian Birds. Melbourne University Press, Melbourne.

Brown A., A. Young, J. Burdon, L. Christidis, G. Clarke, D. Coates, and W. Sherwin (1997) *Genetic indicators for state of the environment reporting.* Australia: State of the Environment Technical Paper Series (Environmental Indicators), Department of the Environment, Sport and Territories, Canberra.

Campbell N. and J. Wallace (1998) *Evaluation of the Feasibility of Remote Sensing for Monitoring National State of Environment Indicators.* Australia: State of the Environment Technical Paper Series (Environmental Indicators), Department of the Environment, Canberra.

Commonwealth of Australia (1990) Atlas of Australian Resources 6: Vegetation. Australian Surveying and Land Information Group, Belconnen, ACT.

Commonwealth of Australia (1996) National Strategy for the Conservation of Australia's Biological Diversity. AGPS, Canberra, ACT.

Council of Australian Governments (1992) National Strategy for Ecologically Sustainable Development. AGPS, Canberra, ACT.

CSIRO (1996a) Pre-1750 Vegetation Mapping for the South Coast Forests Area. Final Report. Phases 1–-3. Vol. 1. Report for NSW National Parks and Wildlife Service. CSIRO Division of Wildlife and Ecology, Canberra.

CSIRO (1996b) Pre-1750 Vegetation Mapping for the South Coast Forests Area. Final Report. Phases 4–-5. Vol. 2. Report for NSW National Parks and Wildlife Service. CSIRO Division of Wildlife and Ecology, Canberra.

CSIRO (1996c) Collection, Data Entry and Classification of Plot Data for the Tumut Study Area. Phase 6. Report for NSW National Parks and Wildlife Service. CSIRO Division of Wildlife and Ecology, Canberra.

DEST (1994) State of the Environment Reporting: Framework for Australia. Department of Environment, Sport and Territories, Canberra, ACT.

Di Gregorio A. and L.J.M. Jansen (1996) FAO land cover classification: a dichotomous, modular-hierarchical approach. Federal Geographic Data Committee Meeting —- Vegetation Subcommittee and Earth Cover Working Group. Washington, 15—-17 October, 1996.

Environment Protection Authority (1997) State of the Environment Reporting: Position Paper. Department of Environment and Natural Resources,; Adelaide.

Fairweather, P. and G. Napier (1998) *Environmental indicators for national state of the environment reporting- Inland waters.* Australia: State of the Environment (Environmental Indicator Reports). Department of the Environment, Canberra.

Federal Geographic Data Committee: Vegetation Subcommittee (1996) FGDC Vegetation and Classification Information Standards (draft of June 1996). USGS, Washington DC.

Friend J. A. (1990) The numbat *Myrmecobius fasciatus* (Myrmecobiidae): history of decline and potential for recovery. *Proceedings of the Ecological Society of AustraliaProc. Ecol. Soc. Aust.* **16:** 369—-377.

Graetz R. D., M.A. Wilson, and S.K. Campbell (1995) Landcover Disturbance over the Australian Continent: a Contemporary Assessment. Biodiversity Series Paper No. 7. Department of the Environment, Sport and Territories,; Canberra.

Greenslade P. and T.R. New (1991) Australia: Conservation of a Continental Insect Fauna. In: N.M. Collins and J.A. Thomas, Eds. "The Conservation of Insects and their Habitats", eds N. M. Collins and J. A. Thomas, pp. 33-70.. Academic Press, London.. pp. 33–70.

Hamblin A. (1998) *Environmental indicators for national state of the environment reporting- the Land.* Australia: State of the Environment (Environmental Indicator Reports). Department of the Environment, Canberra.

Harding R. and D. Eckstein (1996) A preliminary discussion paper on the development of composite indices for state of the environment reporting in NSW. Institute of Environmental Studies, University of New South Wales.

Interim Marine and Coastal Regionalisation for Australia Technical Group (1997) Interim Marine and Coastal Regionalisation for Australia: an ecosystem-based classification for marine and coastal environments. Version 3.2. Environment Australia, Commonwealth Department of the Environment,Draft Version 3.0., Environment Australia, Commonwealth Department of the Environment, Sport and Territories, Canberra. 120 pp.

Montreal Process Implementation Group (1997) Australia's First Approximation Report for the Montreal Process. Department of Primary Industries and Energy, Canberra.

Organisation for Economic Co-operation and Development (1993) OECD Core Set of Indicators for Environmental Performance Reviews. Environment Monographs No. 83., Organisation for Economic Co-operation and Development, Paris.

Specht R.L., A. Specht, M.B. Whelan and E.E. Hegarty (1995) Conservation Atlas of Plant Communities in Australia. Centre for Coastal Management, Lismore, in association with Southern Cross University Press.

State of the Environment Advisory Council (eds) (1996) *Australia: State of the Environment 1996.* An independent report to the Commonwealth for the Environment, Department of the Environment, Sport Territories, (CSIRO Publishing), Melbourne, Vic.

Sun D., R.J. Hnatiuk and V.J. Neldner (1996) Vegetation Classification and Mapping Systems for Australian Forest Management. Bureau of Resource Sciences, Canberra.

Thackway R. and I.D. Cresswell (1995) An Interim Biogeographic Regionalisation for Australia: a Framework for Setting Priorities in the National Reserves System Cooperative Program. Version 4.0. Australian Nature Conservation Agency, Canberra.

Ward T., E. Butler and B. Hill (1998). *Environmental indicators for national state of the environment reporting- Estuaries and the Sea.* Australia: State of the Environment (Environmental Indicator Reports). Department of the Environment, Canberra.

Watkins D. and the Australasian Wader Studies Group (1993) A National Plan for Shorebird Conservation in Australia. Royal Australasian Ornithologists Union Report No. 90.

Williams P. (1996) Measuring Biodiversity Value. World Conservation, IUCN, Switzerland, 1/96, 12–-14.

Appendix 1. Indicators considered for the Key Set but not included

Indicators which were considered for national state of the environment reporting on biological diversity, but were deemed to be more appropriate in other theme reports, or have been judged to be of limited use at the national scale.

INDICATORS OF PRESSURE

- **Human demand on natural resources.** This needs considerable development before being suitable as an indicator. Dealt with further under Human Settlements
- **Area of land approved for clearing but not yet cleared.** Land.
- **Extent and distribution of vegetation types (area, percentage and rate of change) affected by erosion, salinity, soil acidity and other degrading processes.** Land.
- **Degree and extent of pollution on and off-site.** Land, Estuaries and the Sea, Inland Waters.
- **Rainfall** (mean and variability) (global climate change). Atmosphere.
- **Temperature** (sea and land: mean and variability) (global climate change). Atmosphere.
- **Sea level** (global climate change). Atmosphere, and Estuaries and the Sea.
- **Evaporation potential** (global climate change). Atmosphere.
- **Ocean basin currents** (global climate change). Atmosphere.
- **Stocking rate at paddock level for pastoral regions.** Land.
- **Number of exploration/mining licences issued and taken up, area disturbed. Extent of area disturbed by type of mining and exploration.** Land, and Estuaries and the Sea.
- **Rate and volume of logging for structural timber and woodchips by forest types.** Land.
- **Fragmentation of native vegetation in forests by forest types.** Land.
- **Compaction of soils in forests by forest types.** Land.
- **Fire regimes in forests by forest types.** Land.
- **Area grazed and numbers of grazing permits allocated to logged forests by forest types.** Land.
- **Disruption to wildlife movement and migration of some species to other areas by tourism infrastructure.** Deemed to be a low priority indicator and not developed.

INDICATORS OF CONDITION

- **Quantitative genetic variation.** Needs considerable development before being suitable as an indicator.
- **Inter-population genetic structure.** Needs considerable development before being suitable as an indicator.
- **Mating systems.** Needs considerable development before being suitable as an indicator.
- **Ecosystem function (food web analysis, functional groups, canopy health of forests, productivity indices, sea surface chlorophyll, sea current circulation pattern).** Land, Estuaries and the Sea, and Inland Waters.
- **Number and areal extent of vegetation types degraded below a certain level.** Land.
- **Numbers of species of cultural, scientific and social importance.** Natural and Cultural Heritage.
- **Distribution and abundance of transnational species by taxon per IBRA or marine region, or sector.** Deemed to be a low priority indicator and not developed.

INDICATORS OF RESPONSE

- **Number of inter-governmental agreements for collaboration in bioregional planning** (e.g. Murray–Darling Basin Commission, collaborating local governments). Land and Inland Waters.

- **Number of facilitators trained to help resource managers develop ecologically sustainable management practices.** Land and Inland Waters.

- **Number of management themes where a consistent approach is adopted by all relevant jurisdictions.** Land, Estuaries and the Sea, and Inland Waters.

- **Incentives for integrated management** (e.g. Landcare support). Land, Estuaries and the Sea, and Inland Waters.

- **Number and proportion of areas** (farms, pastoral leases etc.) **with management plans incorporating the maintenance of biological diversity** (including conservation or heritage agreements or covenants, coast care and "land for wildlife" type agreements) **compared with total number of holdings** (farms, pastoral leases etc.). Land, and Estuaries and the Sea.

- **Number of Landcare groups incorporating planning for maintenance of biological diversity in their management plans compared with total number of groups.** Land and Inland Waters.

- **Number of private sanctuaries** (e.g. Useless Loop). Land.

- **Number of recovery plans involving knowledge of Aboriginal and Torres Strait Islander peoples and their involvement in planning and/or action.** Not deemed to be an indicator assessing changes in biological diversity.

- **Area of vegetation types managed by Aboriginal and Torres Strait Islander peoples with conservation of biological diversity as an objective.** An indicator more appropriate to State or regional assessment.

- **Amount of money spent on management programs for biological diversity** (e.g. remnant vegetation protection, etc.) **in production landscapes** (e.g. agriculture, pastoral etc.). Land.

- **Area** (and proportion) **of land** (farm, pastoral lease etc.) **subject to conservation-oriented land management practices** (including biodiversity monitoring plots). Land.

- **Amount of money and effort spent on researching problems associated with maintenance of biological diversity in production landscapes and marine regions.** Land.

- **Amount of money and effort spent on managing for the maintenance of biological diversity in production landscapes and marine regions.** Land.

- **Amount of funding for ecological research projects aimed at understanding biological diversity, its functions and involvement in ecological processes compared with total funding available from the public purse.** This indicator is deemed to be too detailed for national state of the environment reporting.

- **Number of public employees engaged in protection of biological diversity** (by level of government) **compared with total public employees.** This indicator is deemed to be too detailed for national state of the environment reporting.

- **Amount** (number) **of legislation, policies** (including number and identity of legislation relating to threatened species and communities) **and international agreements** (e.g. migratory species) **with conservation of biological diversity included.** This indicator is deemed to be too detailed for national state of the environment reporting.

- **Development and application of research techniques for propagating native species** (e.g. propagation of species for reintroduction to the wild). This indicator is deemed to be too detailed for national state of the environment reporting.

- **Recruitment rates of harvested flora and fauna.** This indicator is deemed to be too detailed for national state of the environment reporting.

- **Restocking rates of harvested flora and fauna** (including native fish). This indicator is deemed to be too detailed for national state of the environment reporting.

- **Number of prosecutions for illegal poaching/trafficking.** This indicator is deemed to be too detailed for national state of the environment reporting.

- **Amount of funding** (adjusted for inflation**) spent on, and number of EFT's** (effective full-time equivalents) **involved in, management programs, including on monitoring, policing poaching, trafficking** (e.g. AQIS, ANCA, Marine Management Agencies etc.) and collecting. This indicator is deemed to be too detailed for national state of the environment reporting.

- **Effectiveness of international poaching/trafficking agreements** (e.g. bilateral fishing agreements). This indicator is deemed to be too detailed for national state of the environment reporting.

- **Amount of money and effort spent on researching problems associated with the effects of clearing** (e.g. inventories of vegetation associations, effects of fragmentation, revegetation, habitat restoration-methodology and practice). This indicator is deemed to be too detailed for national state of the environment reporting.

- **Areal extent of protected areas by forest type** (e.g. refer to National Forest Strategy). Land.

- **Effectiveness of sustainable forestry plans with respect to conservation of biological diversity by forest type.** Land.

- **Effectiveness of codes of management practice** (e.g. Forest Management Certification). Land.

- **Amount of recycling** (e.g. paper and wood products). Land.

- **Extent of agro-forestry.** Land.

- **Amount of farming involving native biota** (e.g. aquaculture, emu farming). This is deemed to be a low priority indicator.

- **Number of Landcare groups revegetating with species of local provenance compared with number that are not using local provenance; number and extent of revegetation programs using local species compared with number that are not.** Land.

- **Number of community groups involved in pest or weed management activities.** Land and Inland Waters.

- **Number of organisms declared noxious** (principally agriculture and fisheries). Land, Estuaries and the Sea, and Inland Waters.

- **Reduction in global emissions of CO2 and other greenhouse gasses.** Atmosphere.

- **Effectiveness of international agreements** (e.g. Framework Convention on Climate Change, Greenhouse 21). Atmosphere.

- **Amount of money and effort spent on research problems associated with climate change and its impacts** (including on biological diversity). Atmosphere.

- **Amount of money spent on management programs to minimise the amount of human-induced change in the climate.** Atmosphere.

- **Number of community groups attempting to restore ecological functions to the landscape by degradation issue** (salinity, erosion etc.). Land.

- **Amount and extent of urban bush regeneration including green corridors.** Land.

- **Percentage of degraded land which is being restored and has been restored compared with the total needing to be restored** [broken down by degradation agent (salinity, wind erosion etc.) and type of restoration (nursery stock, direct seeding)]. Land.

- **Spending on rehabilitation programs** (total and percentage of GDP). Land.

- **Extent of local provenance species being returned to the landscape.** Land.

- **Number and extent of revegetation programs relating to salinity, erosion etc.** Land.
- **Amount of nursery stock allocated to revegetation relating to salinity, erosion etc.** Land.
- **Extent of application of efficient irrigation practices.** Inland Waters.
- **Amount of money spent on management programs for salinity, erosion etc.** (e.g. Landcare, Save the Bush, One Billion Trees). Land.
- **Amount of money and effort spent on researching problems relating to issues of degradation and their impacts on biological diversity** (e.g. salinity, erosion etc.). Land.
- **Effectiveness of rehabilitation/restoration programs for mining/exploration areas.** Land.
- **Number of environmental management plans for mining operations.** Land.
- **Amount of money and effort spent on researching methods to minimise the impacts of development on biological diversity.** This indicator is deemed to be too detailed for national state of the environment reporting.
- **Amount of money spent on programs to manage the impacts of development on biological diversity.** This indicator is deemed to be too detailed for national state of the environment reporting.
- **Number of factories and mines with green space allocated to conservation of biological diversity compared with total number of factories.** This indicator is deemed to be too detailed for national state of the environment reporting.
- **The number of urban biological diversity support/watch groups at the community level.** This indicator is deemed to be too detailed for national state of the environment reporting.
- **Change in awareness of issues associated with biological diversity** (e.g. assessment of newspaper articles). This indicator was deemed to be too detailed for national state of the environment reporting and may not be cost-effective for that purpose.
- **Amount of material relating to biological diversity in educational curricula.** This indicator was deemed to be too detailed for national state of the environment reporting.
- **Number of teachers involved in programs relating to biological diversity compared with total number of teachers.** This indicator was deemed to be too detailed for national state of the environment reporting.

List of Environmental Indicator Reports

Environmental indicator reports for national state of the environment reporting are available in seven themes. Bibliographic details are as follows:

Newton P., J. Flood, M. Berry, K. Bhatia, S. Brown, A. Cabelli, J. Gomboso & T. Richardson (in prep.) *Environmental indicators for national state of the environment reporting – Human Settlements,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

Saunders D., C. Margules, & B. Hill (1998) *Environmental indicators for national state of the environment reporting – Biodiversity,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

Manton M. & D. Jasper (in prep.) *Environmental indicators for national state of the environment reporting – Atmosphere,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

Hamblin A. (1998) *Environmental indicators for national state of the environment reporting – The Land,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

Fairweather P. & G. Napier (1998) *Environmental indicators for national state of the environment reporting – Inland Waters,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

Ward T., E. Butler, & B. Hill (1998) *Environmental indicators for national state of the environment reporting – Estuaries and the Sea,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

Pearson M., D. Johnston, J. Lennon, I. McBryde, D. Marshall, D. Nash, & B. Wellington (in prep.) *Environmental indicators for national state of the environment reporting – Natural and Cultural Heritage,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

SoE Reporting homepage:
http://www.erin.gov.au/environment/epcg/soe.html